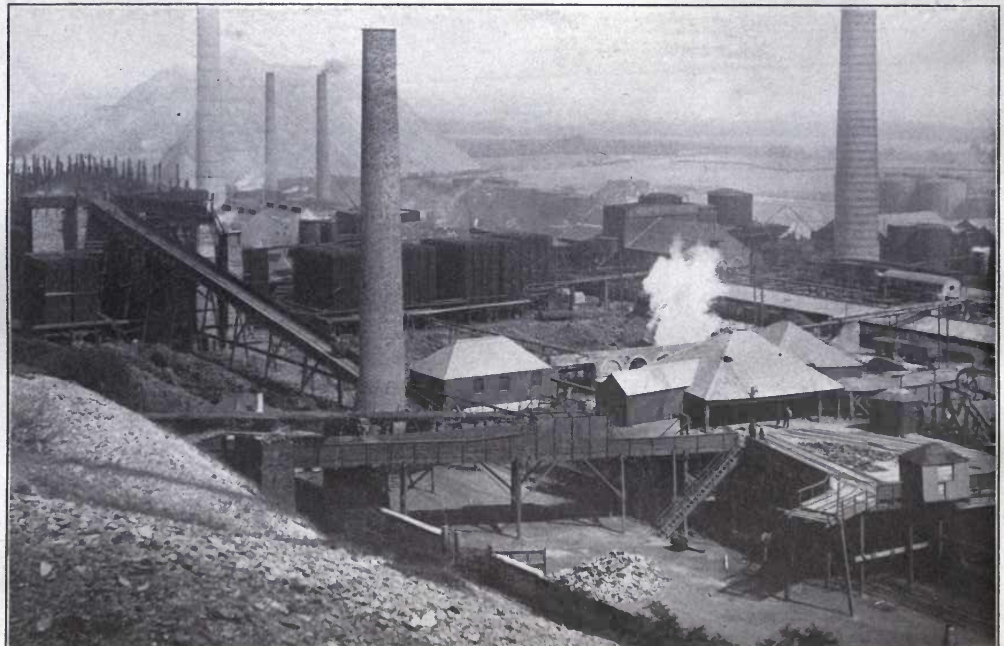

General view of Pumpherston Works. Retorts and Condensers in background. Breaker shed in front. Waste heaps of spent shale in rear.

CANADA

DEPARTMENT OF MINES

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER;

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR.

GEOLOGICAL SURVEY BRANCH

R. W. BROCK, DIRECTOR.

JOINT REPORT

ON THE

BITUMINOUS, OR OIL-SHALES

OF

NEW BRUNSWICK AND NOVA SCOTIA

ALSO, ON THE

OIL-SHALE INDUSTRY OF SCOTLAND

PART I.

ECONOMICS

PART II.

GEOLOGY

BY

R. W. ELLS, LL.D., F.R.S.C.

OTTAWA
GOVERNMENT PRINTING BUREAU
1909

5556—1 Nos. 55 and 1107

GENERAL PREFACE.

The following report on oil-shales is divided into two parts: (1) a monograph on the economic aspect of the subject, dealing with the practical tests made during the summer of 1908 at one of the largest, modern oil-shale works in Scotland, of nearly fifty tons of oil-shale, mined in Albert county, New Brunswick; and (2) a treatise on the distribution, geological position, and character of the oil-shales of various countries—particularly those of Scotland and of eastern Canada; in which is included a description of the mining, retorting, and distillation of oil-shales, and consequent production of crude oil; together with an account of the economic treatment of the various by-products; and a special chapter on the chemical aspects of the mineral oil industry.

The testing of the New Brunswick oil-shales was conducted on a large scale, and with complete success, at the Pumpherston Oil Company's works, MidCalder, Edinburgh county, Scotland. The various operations were performed under the direct supervision of Dr. R. W. Ells—representing the Mines Branch of the Department of Mines, Canada—and of Mr. W. A. Hamor, assistant to Dr. Charles Baskerville, of the Science Faculty of the College of the City of New York—acting for the Albertite, Oilite and Cannel Coal Company, of that city.

Geological and topographical maps—showing the general structure of the district, and distribution of the known areas of the Albert shales (oil-shales) in the counties of Albert and Westmorland, New Brunswick—are being prepared by Mr. Sydney C. Ells, B.A., B.Sc., and will be issued in the near future.

The photographic illustrations of the Pumpherston, and Broxburn Oil Works were specially taken for this report by permission of the managers of the respective plants.

CANADA

DEPARTMENT OF MINES

MINES BRANCH

HON. W. TEMPLEMAN, MINISTER; A. P. LOW, LL.D., DEPUTY MINISTER;
EUGENE HAANEL, PH.D., DIRECTOR.

PART I

REPORT ON TESTS MADE IN SCOTLAND OF OIL-SHALE SENT FROM NEW BRUNSWICK IN THE SPRING OF 1908, WITH A VIEW OF ASCERTAINING ITS ECONOMIC VALUE: ESPECIALLY AS REGARDS THE YIELD OF CRUDE OIL, AND SULPHATE OF AMMONIA

BY

R. W. ELLS, LL.D.

OTTAWA
GOVERNMENT PRINTING BUREAU
1910

No. 55.

PART I.

INVESTIGATOR'S INSTRUCTIONS.

OTTAWA, May 2, 1908.

To Dr. R. W. ELLS, F.R.S.C., &c.,

Geological Survey, Ottawa.

SIR,—You are instructed to proceed to Scotland for the purpose of witnessing and reporting upon the distillation tests to be made for the Albertite, Oilite and Cannel Coal Company, on fifty tons of oil-bearing shales from the New Brunswick shale deposits. Your report is to contain a description of the process in detail, of the machinery employed, and such details as to costs of plant and labour required as will enable prospective operators to form a judgment as to the feasibility of introducing the process successfully in Canada.

Photographs, blue-prints, and working drawings of the different parts of the plant are, if possible, to be obtained, and samples of the by-products taken for analysis in our laboratory.

Yours faithfully,

(Signed) EUGENE HAANEL,

Director of Mines.

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PART I

REPORT ON TESTS MADE IN SCOTLAND OF OIL-SHALE SENT FROM NEW BRUNSWICK IN THE SPRING OF 1908, WITH A VIEW OF ASCERTAINING ITS ECONOMIC VALUE, ESPECIALLY AS REGARDS THE YIELD OF CRUDE OIL, AND SULPHATE OF AMMONIA.

BY

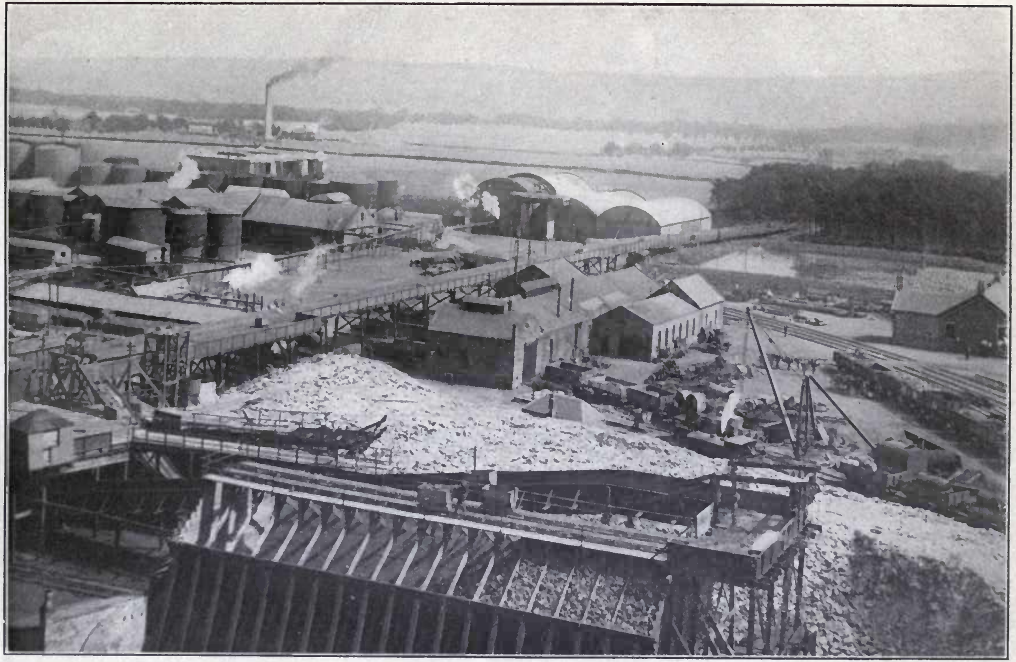
R. W. Ells, LL.D.

Introductory.

Although large sums of money have been spent in attempts to establish a mineral oil-industry in connexion with the so-called Albert shales of Albert and Westmorland counties, New Brunswick—by retorting in the earlier stages of the industry (1860 to 1864), and by subsequent borings at a number of places—all such attempts to place the industry on a commercial basis have failed. The success, however, which has attended the enterprising Scotch companies engaged in the manufacture of oils from shales in Scotland, led the leading company interested in the oil-shales of New Brunswick to send a comparatively large shipment of raw material across the Atlantic, with a view of having the same properly tested in one of the Scotch works. In pursuance of this plan, from 45 to 50 tons of oil-shale were mined during the winter of 1907-8, from one of the bands which occur at Baltimore, Albert county, viz., the George Irving seam. In March, 1908, the Company referred to—the Albertite, Oilite and Cannel Coal Company, of New York, U.S.A.—shipped this output to Glasgow. On representations being made to the Honourable the Minister of Mines, W. Templeman, Esq., M.P., with regard to the great importance of a practical test being made of the oil-shales of Canada, under government supervision, I was commissioned by Dr. Eugene Haanel, Director of the Mines Branch of

the Department of Mines, to proceed to Scotland to supervise the operations, and report on the distillation tests made. This was accordingly done, and the following is an account of my investigations.

On the part of the Albertite, Oilite and Cannel Coal Company, New York, U.S.A., Mr. W. A. Hamor, chief assistant to Dr. Charles Baskerville, the Dean of the Science Faculty of the College of the City of New York, was appointed to oversee the experiments on behalf of that Company, and to especially look after the technical part of the chemistry of the distillation. In July, arrangements were made with Mr. W. Fraser, the managing director of the Pumpherston Oil Company, to undertake the complete testing of the New Brunswick consignment at their works situated at Mid-Calder; since this Company is practically the only one in Scotland provided with an experimental retort of the regulation size, and prepared to do work of this kind on a commercial scale. The shale was accordingly delivered to the works, and on being passed through the retort, was found to work very readily, without clogging, the whole process of the initial retorting, and subsequent fractionation of the crude oil, being entirely satisfactory. The crude oil and sulphate of ammonia were determined from the retort; while the final distillation was carried out in the laboratory. The Company's official report on the testing of these shales, conducted on such a large scale, is interesting technically, and of considerable importance commercially.



General view of Refinery, Pumpherston Works, Scotland.

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Official Report of the Pumpherston Oil Company, Scotland.

Yield of crude oil and sulphate of ammonia obtained from New Brunswick oil-shale, passed through the experimental retort at the Pumpherston works, Scotland.

Date 1908.	Shale used.		Crude Oil.			Sulphate of Ammonia.	Remarks.
			Produced	Sp. gr.	Yield per ton.	Yield per ton.	
	Tons.	Cwt.	Gals.		Gals.	Lbs.	
July 25.	2	4	95·85	·885	43·57	58·55	Not included in average as shale in previous test was not all out of retort until July 26.
" 26.	2	6	99·45	·907	43·24	60·51	
July 27.	2	0	74·44	·920	37·22	75·38	
" 28.	2	5	86·13	·917	38·28	70·62	
" 29.	2	7	90·37	·911	38·88	70·01	
" 30.	2	3	81·80	·920	38·04	83·18	
" 31.	2	5	84·63	·916	37·61	67·46	
Aug. 1.	2	3	96·87	·918	45·06	82·73	
" 2.	2	3	84·32	·921	39·22	79·58	
" 3.	2	4	89·42	·927	40·64	81·88	
" 4.	2	4	79·56	·918	34·59	79·27	Condenser chest choked.
" 5.	2	3	86·75	·910	40·35	55·47	
" 6.	2	5	88·70	·922	39·42	82·81	Condenser chest cleared.
" 7.	2	3	87·38	·918	40·64	100·69	
" 8.	2	4	88·43	·921	40·19	62·45	
" 9.	2	3	95·72	·918	44·52	79·63	
" 10.	2	3	91·28	·911	42·46	81·31	
" 11.	2	0	79·90	·925	39·95	71·14	
" 12.	2	0	87·58	·925	43·79	85·03	
	36	15	1,473·28	·919	40·09	76·94	

	Tons.	Cwt.
Total shale received................	41	5
Put through before test	4	10
Put through during test...	36	15

Total .... 41 tons, 5 cwt.

Signed for the Pumpherston Oil Co., Ltd.

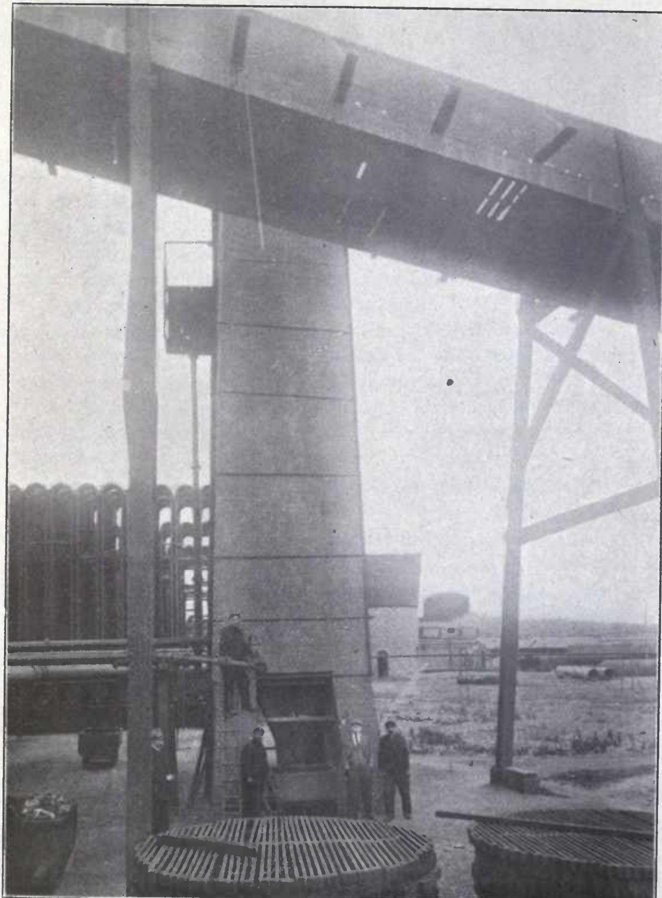
G. M. McCulley,
Assistant Secretary.

August 13, 1908.

On the whole, therefore, it may be said that the results of the retorting of these shales on a working basis, are eminently satisfactory, both as regards the yield of crude oil and sulphate of ammonia: exceeding in these respects the greater part of the Scotch shales, which have been worked for many years.

The peculiar differences in the yield of these substances from day to day are difficult of explanation, except that they may be due to variations in the composition of the mineral as taken from the shale-bed itself; possibly to carelessness in mining, or to the inclusion of portions of wall rock in some parts of the shipment. The Baltimore bed from which this special shipment was selected, is not one of the best; judging from the physical character of the shales themselves, and by analyses of other beds in the vicinity. This particular shale may be described as being of medium grade: as regards both its oil and ammonia contents. Had similar tests been made of the oil-shales from other local beds they would, doubtless, have given even better results. This has been definitely ascertained by the analyses recently made by Dr. Baskerville, of the College of the City of New York; as will appear from his report on tests of material from several seams found near Baltimore, and other parts of the shale field. In fact shales from the Baizley seam, and from that near E. Stevens house, have shown a much larger percentage both in crude oil and in sulphate of ammonia than the consignment tested in Scotland; due to the different composition of the shale, which is largely of the curly variety, and shows its rich character by the numerous black streaks of a mineral resembling, in some respects, albertite.

At the close of the process of retorting, the crude oil was ready for the fractionation test; which was carried out by the chief chemist of the Company, Mr. E. M. Bailey. This part of the work was very systematically done; and Mr. W. A. Hamor, of New York—one of Dr. Baskerville's assistants—supervised the progressive processes employed. The report of Mr. Bailey, chief chemist, endorsed by the manager, is very satisfactory, and may here be given. The fractionation was carried out in the Company's laboratory; since it was impossible to make such a test in the large works of the Company, owing to the necessity, in such a case, of stopping the regular process of manufacture of their own oil-products.



Experimental Bryson Retort, used for testing New Brunswick shale, Pumpherston Works, Scotland.

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The official report on fractionation is as follows:—

THE PUMPHERSTON OIL COMPANY, LIMITED.

Test of shale received from Canada, through Dr. R. W. Ells. Crude oil made between July 27, and August 12, 1908, in the Pumpherston Retort.

The crude oil was dealt with by two different methods, for the purpose of obtaining refined products of good quality.

The liquid products produced by both methods were practically identical in quality when finished; but the colour of the crude paraffin wax or scale, derived from method B, was much superior to that produced by the use of method A; which is a point of considerable practical importance, when the conversion of the crude wax into refined wax of marketable quality is under consideration.

It is probable, however, that further treatment with acid (before the soda treatment) of the crude distillate obtained by method A, would have the effect of so transforming the material that a crude wax of good colour could be subsequently extracted.

As far as the percentage yield of refined products is concerned, however, the results are very similar, whichever method of refining is adopted.

The following is an outline of the scheme for refining the crude oil:—

Method A—The crude oil was distilled and fractionated into (1) crude naphtha, and (2) crude distillate. The crude distillate was treated with sulphuric acid (1·84 sp. gr.) and caustic soda solution (1·35 sp. gr.), then again distilled, and fractionated into (3) crude burning oil, (4) heavy oil, and (5) residuum.

Nos. (1) and (2) were further refined by treatment with acid and soda, and distillations.

No. (4) was cooled to a low temperature and filter pressed, to extract the solid paraffin (6). The blue oil (7) was filtered from (4), treated with acid (1·72 and 1·84 sp. gr.), and soda (1·34 sp. gr.), distilled off solid caustic soda, and fractionated into various products; the refining of some of these being completed by a final treatment with acid and soda.

Method B—The crude oil was treated with sulphuric acid (1·22 sp. gr.), then distilled and fractionated into (1) crude naphtha, and (2) crude distillate. The crude distillate was treated with sulphuric acid (1·72 and 1·84 sp. gr.) and caustic soda solution (1·35 sp. gr.),

then again distilled, and fractionated into (3) crude burning oil, (4) heavy oil, and (5) residuum.

No. (4) cooled and filtered gave solid paraffin (6) and blue-oil (7). No. (7) was then treated with acid (1·84 sp. gr.) and soda, distilled off caustic soda, and fractionated into various products; the refining of some of these being completed by a final treatment with acid and soda.

TABULAR STATEMENT OF REFINED PRODUCTS.

(Method A.)

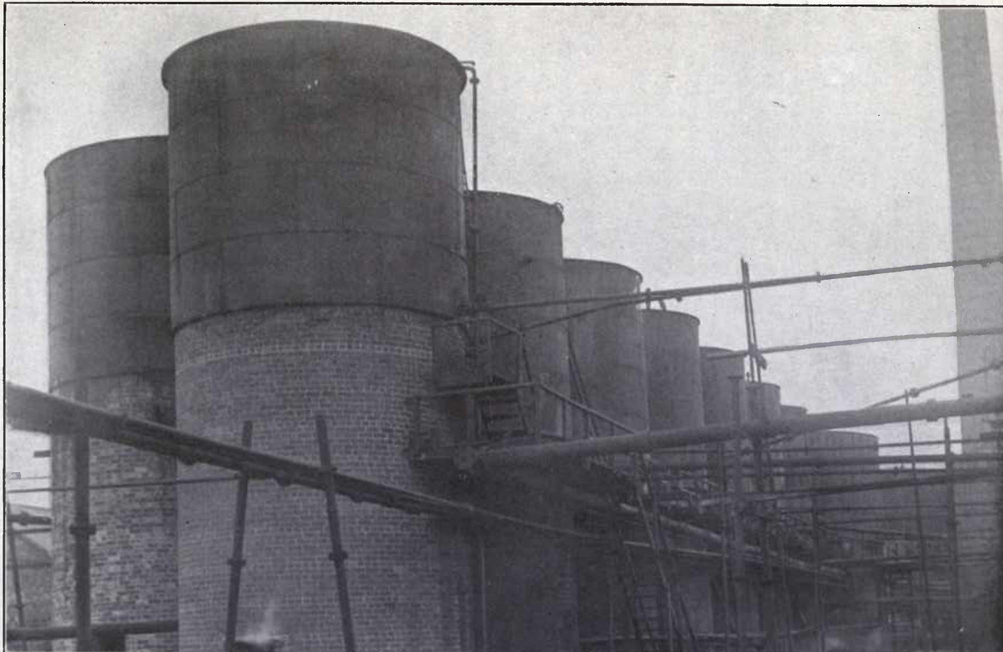
Product.	Gallons per 100 gals. of Crude Oil.	Specific Gravity. 60° F.	Setting Point. Deg. F.	Melting Point. Deg. F.
Heavy naphtha	1·62	0·7670		
Burning oil.	10·04	0·7954		
Gas oil	14·87	0·8431	25°	
Cleaning oil.	2·83	0·8713	25°	
Lubricating oil	9·58	0·8957	30°	
Crude wax	2·26	....	....	112·26°
"	0·93	....	....	101·0°
"	....			
Residuum from blue oil (refined)	0·28			
" from treated crude distillate (refined)	1·27			
	43·68			

Total crude wax containing 4% oil = 3·19 gals. = 2·907 gals. refined wax, melting point 108·98.
Sulphuric acid used in refining 100 gals. crude oil = 4·705 gals. (1·84 sp. gr.).

(Method B.)

Product.	Gallons per 100 gals. of Crude Oil.	Specific Gravity. 60° F.	Setting Point. Deg. F.	Melting Point. Deg. F.
Heavy naphtha	1·45	0·7670		
Burning oil.	11·50	0·7955		
Gas oil	13·04	0·8450	25°	
Cleaning oil	1·56	0·8705	26°	
Lubricating oil	11·03	0·8935	30°	
Crude wax	2·21	....	....	111·3°
"	0·60	....	....	104°
"	0.16	....	....	84°
Residuum from blue oil (refined)	0·57			
" from treated crude distillate (refined)	1·95			
	47·07			

Total crude wax containing 4% oil = 2·97 gals. = 2·2707 gals. refined wax, melting point 108·38° F.
Sulphuric acid used in refining 100 gals. crude oil = 4·68 gals. (1·84 sp. gr.).
Flash point of burning oil: 117° F. (Abel Close test.)
Viscosity of lubricating oil: 200″ (seconds) at 70° F. (Redwood's apparatus.)



Battery of Stock Tanks, Pumpherston Works, Scotland.

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REMARKS ON QUALITY OF PRODUCTS AND SAMPLES.

Considering the quality of the crude oil and the nature of the mineral (which we do not consider a true oil-shale) from whence it is derived, I consider the quality of the refined products very satisfactory.

The samples are representative of the products obtained by both methods of refining. It will be easily understood, however, that it is practically impossible to mix these in precisely their due proportions, hence the physical constants of the samples are not perfectly identical with those given in the tabular statement, but are only a close approximation thereto.

As it is impossible on a small scale to extract all the lower melting point portions of the crude wax by direct cooling and filter-pressing; the specific gravity and setting point of the cleaning oil and lubricating oil given in the statement differ somewhat from those of the samples submitted; the specific gravity of these oils, and yield of low melting point crude wax (equivalent to 0·93 and 0·73 on the crude oil) being calculated to what would be obtained by a reduction in setting point to that obtainable on the manufacturing scale. The calculation is based on data derived from actual experiment, and is perfectly reliable.

It must be understood, however, that the yield of high M.P. crude wax (equal to 2·26 and 2·21 per cent) is that actually extracted and determined.

(Signed) EDWIN M. BAILEY,
Chemist.

PUMPHERSTON OIL WORKS,
MidCalder, Scotland, September 21, 1908.

THE PUMPHERSTON OIL COMPANY, LIMITED.

Test of shale from Canada through Dr. R. W. Ells. Crude oil made from July 27, until August 12, 1908, in the Pumpherston Patent Retorts. The retort gases, if passed through an oil scrubber, would yield some crude naphtha.

Analysis of uncondensed gas, after leaving ammonia water scrubber and returning to retort combustion chamber:—

(Average of three analyses of five samples) (Air-free).

Carbon dioxide (CO_2)..	28·67	per cent.
Carbon monoxide (CO)...	5·06	"
Olefines (C_nH_m)...	1·33	"
Methane (CH_4)..	11·02	"
Hydrogen (H_2)..	52·92	"
	100·00	"

Calorific value = 305·1, B.T.U. per cubic foot, (N.T.P.).
Specific gravity = 0·613, (Air = 1).
Weight per cubic foot = 0·0492 pounds.

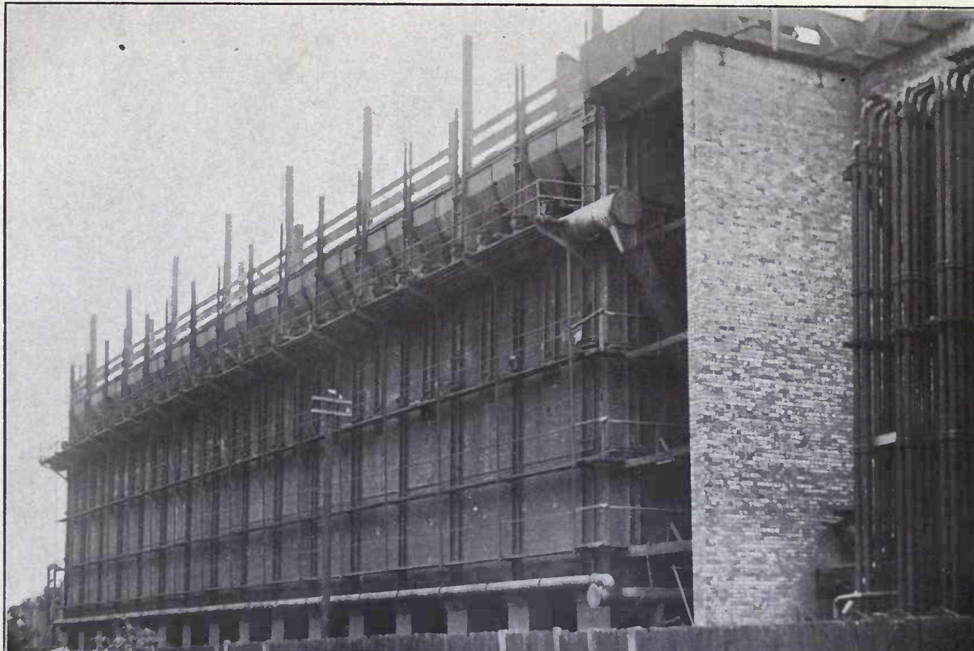
(Signed) EDWIN M. BAILEY,
Chemist.

Signed for the Pumpherston Oil Co., Ltd.
R. G. McCULLEY,
Assistant Secretary.

PUMPHERSTON WORKS,
MidCalder, Scotland, September 19, 1908.

While a number of analyses of the oil-shales of New Brunswick have been made from time to time by various persons, the places from which the greater number of the samples were collected could not be definitely located, hence the results obtained are of little commercial value. After my return from Scotland a number of the shale areas were again visited, and well-chosen samples weighing some twenty pounds each, were collected from several places: including Taylorville, Albert Mines, Baltimore, Turtle creek, and Hayward brook; in order that a thorough analyses of these might be made in the laboratory of the Mines Branch of the Department of Mines. These analyses, when completed, will give accurate and reliable results as regards crude oil and sulphate of ammonia, and will be of great economic value. Arrangements were also made to obtain samples from several localities in Nova Scotia; but the samples from these places have not yet arrived.

In the meantime the results of analyses made in the laboratory of Dr. Charles Baskerville, Dean of the Faculty of Science in the College of the City of New York, are given, as illustrating the economic values of these shales in crude oil and sulphate of ammonia; and for the sake of comparison with known results obtained from the Scotch shales at the principal works in Scotland.



Bench of Retorts, with Condensers attached, Pumpherston Works Scotland.

5656—p16

Analyses of oil-shales from New Brunswick, made by Mr. W. A. Hamor, in the laboratory of the College of the City of New York, under the direction of Dr. Charles Baskerville:—

Locality.	Imp. gallons of crude oil per ton.	U. S. gallons of crude oil per ton.	Sp. gr.	Pounds of ammonium sulphate per ton.
Shale retorted in Scotland......	40	48	0·920	77
George Irving's seam—same as above........................	39	47	0·895	76
Baizley farm, Baltimore..........	54	65	0·895	110
E. Stevens farm, Baltimore.....	49	59	0·892	67
Hayward brook—branch of Prosser brook........................	30	35	0·895	75
Adams farm, Taylorville...... ...	43	51	0·900	93
A. Taylor's farm, No. 1..........	48	58	0·910	98
A. Taylor's farm, No. 2..........	37	44	0·925	110
Sample (85 lbs.) from Baltimore—run in 1907....................	51	61	0·910	111

Samples of the bands of oil-shale which outcrop on Frederick brook at the Albert mines, also from Baltimore, and from Taylorville, were collected during the past season for the Mines Branch of the Department of Mines. A new plant for the distillation of oil-shales has recently been installed in the chemical laboratory of the Mines Branch, Ottawa, and the analyses of the above-mentioned samples, made by Mr. H. A. Leverin, are submitted herewith. It will be perceived that the percentages both in crude oil and in sulphate of ammonia are very high—in most of the examples.

Locality.	Imp. gallons of crude oil per ton.	Sp. gr.	Pounds of sulphate of ammonia per ton.
Albert Mines—			
Sample No. 1..............	48·5	0·898	82·8
" 2..................................	38·9	0·892	60·3
" 3:..........	45·5	0·891	48·0
" 4..	43·5	0·896	56·8
" 6................................	27·0	0·895	49·1
Albertite—.............	112·0	0·857	65·4
Two samples of the thin-bedded or 'paper' shale from Albert mine, of which there are immense quantities, gave..........	40·8	0·892	41·0
	33·5	0·890	47·0
Baltimore shale—			
Baizleys..................................	52·0	0·904	112·2
E. Stevens.............	45·5	0·892	70·0
Turtle creek, West br. grey sh......	56·8	0·891	30·5
Taylorville shale—			
Adams farm No. 1.......................	42·3	0·897	96·5
" " 2.......................	47·3	0·901	88·7
Taylors farm No. 1......................	46·8	0·902	85·0
" " 2......................	45·0	0·903	101·0

Analyses of grey and black shales of Baltimore made by Ricketts and Banks, N.Y., 1893.

From the grey bands, probably of Turtle creek—

Moisture	1·10	1·54
Vol. matter	45·32	51·22
Fixed carbon	1·29	3·03
Ash	50·69	44·21
Sulphur	1·70	....
	100·00	100·00

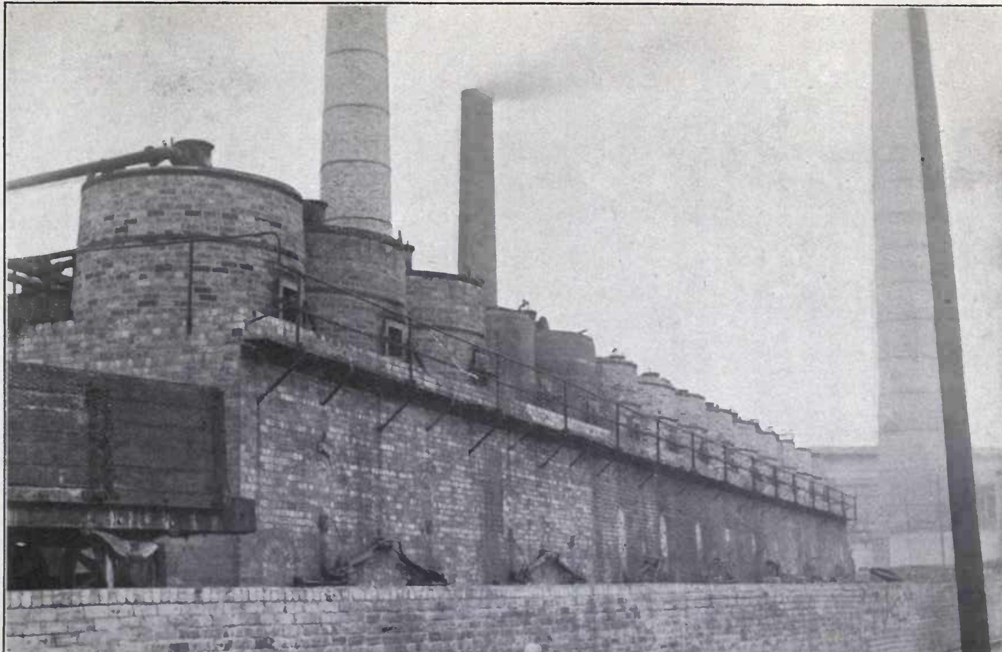
From the black bands—

Moisture	0·36	0·64
Vol. matter	39·50	45·52
Fixed carbon	3·00	5·05
Ash	56·10	48·79
Sulphur	1·04	....
	100·00	100·00

THE SCOTCH OIL-SHALE INDUSTRY.

Inasmuch as considerable interest is now being taken in Canada with regard to the development of the Scotch oil-shale industry, the following extracts from a recent paper in 'Economic Geology,' 1908 —by Mr. D. R. Steuart—on the early history of the oil-shale industry of Scotland, may be given:—

'The Torbanehill mineral was used for about twelve years in Scotland for paraffin oil manufacture. Some was exported to the continent of Europe, and to America for the same purpose. After that time (or about 1862) it became exhausted. The distillation of shale was commenced early in the sixties and has continued ever since. Gas and parrot coals were also used. Throughout the Coal Measures many bands of shale were found, often in connexion with the coal seams. Above the coal seam there was often a thin bed of shale, and under the coal a thin bed of black-band ironstone. Shale seams were worked in the Clyde valley coal-fields, in connexion with the Flint and Virtuewell coals, the mussel-band ironstone, and the Kiltongue coal. In Fife, Midlothian, Lanarkshire, Stirlingshire, Renfrewshire, and Ayrshire, shale and bastard parrot coals were worked in the Coal Measures, Millstone-grit, and mountain limestone.



Battery of Stills, front view, Pumpherston Works, Scotland.

In the early and flourishing days of the industry, shale or gas coal was worked for oil at various places in the English coal-fields also, namely in Yorkshire, Cheshire, Lancashire, and Staffordshire, and especially in Flintshire, North Wales. In Flint, the Leeswood cannel-coal seam was from 5 to 6 feet thick, in a limited basin-shaped area. All have been stopped for years.

'When American petroleum was imported in large quantities the prices of products fell, the richer cannel-coals were used for gas making, and the bastard parrot coals and shales of the Coal Measures—both in England and Scotland—ceased to be mined; so that for many years the manufacture has been confined to the shales of the Calciferous sandstone.'

The highest seam formerly worked for oil in the West Lothian district was the Torbanehill mineral, already referred to. This occurred at the base of the Coal Measures, overlying the Millstone-grit. In this connexion it holds the same geological position as the stellarite found in the Pictou coal-basin of Nova Scotia, where this mineral occurs near the base of the Coal Measures, and overlying the Millstone-grit of that area.

In the list of seams which occur in the Scotch shale field, this bed of Torbanehill mineral may be styled No. 1—as regards position. The yield of oil was high, ranging from 90 to 130 gallons per ton.

The other shales worked from time to time in the Scotch areas, several of which have long since been abandoned, may be described in descending order:—

No. 2. A seam of 11″, Levenseat shale, yielding 29 gallons per ton, worked probably as the parrot coal seam, belonging to the lower Carboniferous limestone formation. Yield of oil about 34 gallons, and of sulphate of ammonia about 8½ pounds.

No. 3. From the Calciferous Sandstone formation, the upper shale is the Raeburn or Damhead shale, 3′–0″ to 5′–0″ thick, sometimes 6′–0″, including layers of blaes or fireclay. Worked at West Calder, Tarbrax, and Charlesfield. Oil 54½ gallons, sulphate of ammonia 14 pounds.

No. 4. Mungle or Steuart shale, 2′–0″ thick at West Calder. A 2 ft. seam of coal was worked at Broxburn by Robert Bell, together with 17″ shale, yielding 27 gallons of oil per ton. There were 4″ of ironstone above the shale. At another point in the Broxburn field there were 17″ of shale, giving 41 gallons crude per ton,

the average yield being 34 to 35 gallons oil, and 30 pounds sulphate of ammonia.

No. 5. The grey shale of Addiewell, about 20″ thick, the crude oil yielding much solid paraffin; the shale giving crude oil 28 gallons, and sulphate of ammonia from 13 to 18 pounds.

No. 6. The Fells shale, from 3′–0″ to 5′–0″ thick at West Calder, and in places about 7′–0″; mined at Addiewell, Tarbrax, Breich, Seafield, Hermand, and Pentland. It is the principal shale of the West Calder district. Yield of oil from 26 to 40 gallons, and of sulphate of ammonia 20 to 35 pounds.

No. 7. Wee shale of Oakbank; 2′–0″ thick, not worked; oil, 36 gallons.

No. 8. Big shale of Oakbank; 4′–6″ thick, used at Oakbank; oil, 22 gallons.

No. 9. Wild shale of Oakbank, or Lower Big shale, the grey shale of Broxburn; worked at Oakbank and Broxburn, 6′–0″ thick; oil, 29½ gallons; sulphate of ammonia, 34 to 41 pounds.

No. 10. The Curly shale of Oakbank and Broxburn; mined at Broxburn, Oakbank, and Dalmeny; 6′–0″ thick; oil, 22 gallons; sulphate of ammonia, 35 pounds.

No. 11. The Broxburn shale, varies in oil from 10 gallons to 50 gallons, includes several seams, of which at Broxburn there are three, the Broxburn grey, 6′–0″ thick, giving about 23 gallons oil and 35 pounds of sulphate of ammonia; the Broxburn Curly, 5′–6″ thick, with 26 gallons of oil, and 38 pounds of sulphate of ammonia; and the Broxburn, from 5 to 6 feet thick, giving oil from 28 to 35 gallons, and 40 pounds of sulphate of ammonia.

No. 12. Lower Wild shale of Oakbank, 5′–6″ thick, gives oil 19¼ gallons per ton.

No. 13. The Dunnet shale, from 4′–0″ to 12′–0″ thick, yields 24 to 33 gallons oil and 24 pounds sulphate of ammonia. The shales vary considerably at different points.

No. 14. The Oakbank New shale, 8′–6″ thick, gives 20½ gallons oil.

No. 15. The Barracks shale, sometimes 8′–0″ thick, yields from 18 to 22 gallons oil.

No. 16. The Pumpherston seams, five in number, as under:—

(1) or Jubilee seam; thickness, 8′–0″; oil 18 gallons, sulphate of ammonia 55 pounds.

(2) Maybrick seam; 5′–0″ thick; oil 16 gallons, sulphate of ammonia 60 pounds.

(3) or Curly seam; 6′–0″ thick; oil 20 gallons, sulphate of ammonia 60 pounds.

(4) or Plain seam; 7′–0″ thick; oil 20 gallons, sulphate of ammonia 60 pounds.

(5) or Wee seam; 4′–0″ thick; oil 18 gallons, sulphate of ammonia 60 pounds.

The History of the Oil-shale Industry in Scotland.

For much of the information on this subject the writer is indebted to the notes of Mr. D. R. Steuart, and to the volume by Mr. Iltyd Redwood, 1897, entitled: 'A Practical Treatise on Mineral Oils and their By-products.' Apparently, the first enterprise in the manufacture of crude oil in Scotland was begun in 1848 by Mr. James Young; the source of supply being a small spring of petroleum, found in a coal-pit at Alfreton, Derbyshire, from which was manufactured illuminating and lubricating oils, as well as solid paraffin. Upon the failure of the native mineral oil, attention was directed to beds of bituminous coal, and a number of these were tested, with a view of obtaining crude oil by distillation. Upon the discovery of the Torbanehill mineral[1] in 1850, this was substituted for bituminous coals, and proving satisfactory, distillation works were erected at Bathgate, a few miles west of Edinburgh. On the exhaustion of the torbanite, about 1862, oil-shale deposits were utilized.

In the working of torbanite the yield of crude per ton was about 100 to 120 gallons, with some 22 pounds of paraffin—which at that time was regarded as of little value. The commercial importance of the paraffin was realized about 1858, and since that date it has formed one of the profitable by-products derived from the distillation of crude oil.

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[1] TORBANITE.—A variety of cannel coal of a dark brown colour, yellowish streak, without lustre, having a subconchoidal fracture, H=2·25; G=1·17—1·2. Yields over 6 per cent of volatile matter, and is used for the production of burning and lubricating oils, paraffin, illuminating gas. Named from the locality at Torbanehill, near Bathgate, in Linlithgowshire, Scotland. (Dana.)

In the substitution of oil-shales for the torbanite, it was found that while the shale was much poorer in crude oil, it was much richer in paraffin, and other volatile substances: notably ammonia gas, which, by chemical combination with sulphuric acid, is transformed into the very valuable fertilizing agent known as sulphate of ammonia. The shales first used for distillation yielded from 40 to 50 gallons of crude oil per ton. A large portion, however, gave much lower results in oil; but was found to give higher results in ammonia. As progress was made in the process of manufacture, it became an established generalization that, shales low in crude oil were correspondingly high in ammonia. It has also been found that, not only is the yield of crude oil from the pyroschists[1] mined in most parts of the oil-shale field much less than in the earlier days of the industry, but that the greater yield of oil is from those procured from the higher beds of the series; decreasing with depth. As an offset to the last mentioned feature, however, continued improvements in distillation methods, and modification of machinery, appliances, processes, etc., have enabled the leading companies to manufacture much more cheaply; while the increased values of the principal by-products has, in recent years, been such, that the industry as a whole have been placed on a very remunerative basis.

It is impossible in this condensed description of the leading features of the industry, to set forth in detail the numerous changes which have taken place in the manufacture of crude oil, and in the various processes of fractional distillation since the early days—fifty years ago. It may suffice, however, to state that the whole process of extracting crude oil from pyroschists, and the subsequent fractional distillation thereof, has exhibited a constant series of improvements: carefully considered economies being introduced at every stage of the several processes, and great attention being directed to the utilization of the valuable by-products. In time, through the failure of the supplies of Peruvian guano and the impending exhaustion of the Chilian nitrate beds, attention was directed to the manufacture of sulphate of ammonia, which is now extensively used as a fertilizer.[2] This is now one of the leading by-products of the mineral oil industry, and one of the principal sources

[1] The term *pyroschist* is used as being synonymous with oil-shale. *See* Chemical and Geological Essays by Dr. T. Sterry Hunt, 1897, p. 177.

[2] Sulphate of ammonia contains of nitrogen about 20 per cent of its weight, and is, therefore, richer in that element than its chief rival—nitrate of soda, which contains about 16 per cent of its weight of nitrogen.

of profit from the distillation of the oil-shale. With the most recent types of retorts the yield of sulphate of ammonia has markedly increased: as high a percentage as 60 to 70 pounds per ton being now obtainable from certain grades of the oil-shales. Though the market price of this substance has fluctuated widely—reaching in 1880, £22 per ton; but declining in 1890 to £8 per ton—its subsequent revival to £12 has saved the industry. Occasionally, large profits are still obtainable from the distillation of shale low in oil contents, but comparatively high in ammonia. The same remark applies—to some extent—to the manufacture of paraffin, which in some of the works is still a source of profit.

It may be of interest to mention—as showing the fluctuation and development of the oil-shale industry—that in the forty-five years since its commencement, no less than 117 mineral oil works have been in operation; and taking into consideration the several changes of ownership, some 140 different proprietors have been engaged in this business. It is, however, only fair to state, in this connexion, that the profits of the industry have been far from uniform: as will be seen from the statement taken from Iltyd Redwood's Manual, 1897. In this it is stated that for the years 1891-2 a total profit of £85,492 was made, by four of the companies then working; but only two of these made any allowance for depreciation. The remaining four companies had a total loss on the year's working of £32,576; so that the total profits of the eight companies were £52,916. On the other hand, the profits in recent years of several of the principal companies now engaged in the mineral oil business are reported as being very large: reaching 50 per cent on the capital invested; so that on the whole it may be said that the percentage of profits—apparently largely derived from the by-products—has materially increased; and that with several of the leading companies the oil-shale industry is, at the present time, in a very flourishing condition.

As indicating the fluctuations of the mineral oil business, it may be noted (based on the figures given in Mr. D. R. Steuart's history of the oil-shale industry) that of the original large number of companies at one time operating, this number, in Scotland, had in 1871 decreased to 51; and in the subsequent ten years had further decreased to 30. In 1894, there were only 13 of these companies in Scotland; in 1906 this number had declined to 6; but he adds the significant fact that, in spite of this reduction, the output had not decreased.

STATISTICS.

Full and reliable data cannot now be obtained, but the following figures as given by Mr. Steuart may be regarded as fairly approximate:—

In 1903, the amount of shale distilled was..	2,400,000 tons.
Crude oil produced..........	54,000,000 gallons.

From this the marketable products obtained were:—

Burning oil and naphtha...........	19,000,000 gallons.
Gas oils....................	6,000,000 "
Lubricating oils................	8,800,000 "
Paraffin wax..................	22,000 tons.
Sulphate of ammonia..........	40,000 "
Total value of products.......	£1,800,000

In 1904 the amount of shale distilled was...	2,333,062 tons.
Value..................	£544,346

From another estimate:—

Shale in 1904.................	2,709,840 tons.
Crude oil produced..............	62,932,400 gallons.

Marketable products:—

Naphtha....................	2,517,296 gallons.
Burning oils..................	16,991,748 "
Gas oils....................	37,997 tons.
Lubricating oil...............	39,487 "
Wax.....................	22,476 "
Sulphate of ammonia..........	49,600 "

In 1906, the total shale production in Scotland was 2,545,582 tons. The refined products for the year were:—

Spirit or naphtha, sp. gr., 0·680 to 0·750..about	2,500,000 gallons.
Burning oils, sp. gr., 0·790–0·830...... "	17,000,000 "
Gas or intermediate oils, sp. gr., 0·850–0·870 "	38,000 tons.
Lubricating oils, sp. gr., 0·965–0·900.... "	40,000 "
Solid paraffin wax, m. points, 100–130° F.. "	22,500 "
Sulphate of ammonia, over..........	50,000 "
Still coke, selling at 60 to 70 shillings per ton..	5,000 "

In 1907, the production of oil-shale in Scotland amounted to 2,775,799 tons, the average yield of crude being 23 gallons.

Quantities and products of shale at intervals from 1871 to 1893:—

—	1871. 51 works.	1879. 18 works.	1887. 13 works.	1893. 13 works.
Shale ....Tons.	800,000	850,000	1,869,300	1,947,842
Crude oil..................Gals.	25,000,000	29,000,000	52,876,700	48,969,050
Naphtha, burning and gas oils............ "	11,250,000	11,400,000	21,680,000	20,452,341
Lubricating oil.......... "	2,500,000	5,000,000	9,000,000	8,765,289
Paraffin solid............Tons.	5,800	9,200	22,846	19,130
Sulphate of ammonia..... "	2,350	4,750	18,483	28,000

EXTENT OF THE INDUSTRY AS REGARDS RETORTS, ETC.

The exact number of retorts engaged in the business of oil-shale manufacture in Scotland could not be ascertained, since no returns were available from either the James Young Company, or from the James Ross Company. Figures were, however, furnished by the Pumpherston; Tarbrax; Dalmeny; Oakbank, and Broxburn Companies: from which the following may be given:—

Pumpherston Oil Company, three plants, viz.—

Main plant: with three benches of 64 retorts.. ..	192	
Deans..	156	
Seaforth..	130	
This number will probably be doubled in 1909.	——	478
Tarbrax Company—		
Three benches of 64 retorts..		192
Dalmeny Company—		
Three benches of 64 retorts..		192
Oakbank Company—		
Main plant: two benches of 64 retorts..	128	
Niddry castle: two benches of 64 retorts..	128	
	——	256
Broxburn Oil Company—		
Main plant: three benches of 64 retorts..	192	
Roman camp: three benches of 64 retorts..	192	
	——	384
		——
		1,502

The capacity of the Oakbank plant will probably be doubled in 1909. The main plant of the Broxburn contains 3½ benches, or 224 retorts, of which a half bench is held as a reserve.

The Broxburn plant puts through about 1,600 tons of shale in a day of 24 hours.

As nearly as could be ascertained—though the price varies according to varying conditions—the cost of mining the shale may be placed at 5 shillings per ton; and the cost of putting the same through the retort, at about one shilling and sixpence per ton.

Miners' wages are fixed periodically, and at present (1908) are as follows:—

Miners..	6s. 3d. per day.
Helpers..	5s. 9d. "

Two men usually work together, and produce jointly about 8 tons per day on a seam of 6′–0″ to 7′–0″ thick; or an average of 4 tons per man. On a smaller seam, say of 5′–0″ to 6′–0″, about 6 tons for each shift of two men.

In the 57 years since the establishment of the oil-shale industry in Scotland some 120 different works have started and collapsed—in many cases without paying a dividend. In the industry at the present time (1908) about 8,300 men are employed, of whom nearly 4,000 are miners; the wages paid annually being about £700,000.

As a basis of calculation it may be added that generally in Scotland the cost of mining and retorting the shale—while varying considerably in different places owing to local conditions—is about $1.86 per ton, divided as follows:—

Mining and taking to retort mouth..	$1 00
Retorting..	40
Manufacture of sulphate of ammonia..	46
	$1 86

Prices of various products at intervals of ten years:—

—		1873.			1883.			1893.			1903.		
		£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Burning oil............	per gal.	0	1	5	0	0	$5\frac{3}{4}$	4	0	$5\frac{1}{4}$	0	0	$5\frac{3}{4}$
Heavy oil	" ton.	20	0	0	9	10	0	5	0	0	6	0	0
Refined paraffin, oil	" lb.	0	0	10	0	0	4	0	0	5	0	0	3
Crude paraffin, scale....	" "	0	0	5	...	...	...	0	0	$2\frac{1}{2}$	...	...	...
Ammoniun sulphate....	" ton.	20	0	0	17	0	0	10	0	0	12	10	0

Statistics showing gradual yearly increase in shale output since 1873:—

Year.	Tons.	Year.	Tons.	Year.	Tons.	Year.	Tons.
1873....	524,095	1881...	912,171	1889...	1,986,990	1897...	2,211,617
1874....	361,910	1882...	994,487	1890...	2,180,483	1898...	2,133,409
1875....	424,026	1883...	1,130,729	1891...	2,337,932	1899...	2,208,249
1876....	541,273	1884...	1,469,649	1892...	2,077,076	1900...	2,279,879
1877...	684,118	1885...	1,741,750	1893...	1,947,842	1901...	2,350,277
1878....	645,939	1886...	1,699,144	1894...	1,967,007	1902...	2,105,953
1879....	712,428	1887...	1,390,320	1895...	2,236,224	1903...	2,009,265
1880....	730,770	1888...	2,052,202	1896...	2,435,555	1904...	2,333,062

Cost of Plants for Retorting and Subsequent Distillation of Oil-shale.

As a part of the instructions given in connexion with the test of the shale shipment in Scotland was to ascertain as closely as possible the cost of erecting the necessary plants for the retorting of the shale and the subsequent distillations, the following information obtained from Mr. Norman Henderson, manager of the Broxburn Oil works, Mr. James Bryson, manager of the Pumpherston Oil works, and Mr. A. F. Craig, of Paisley, a large manufacturer of such plants, may be given. The figures given are with reference to plants laid down in Scotland, and when applied to points in Canada will be somewhat greater, since allowance must be made for freight, possible custom duties, etc., and extra expense of erection.

The cost is based on the daily capacity of a retort, which is placed at four tons, and is given as say £65 per ton capacity. Thus for a

4 ton retort the cost of each retort laid down at the works in Scotland would naturally be £260. Each bench of retorts consists of 64 retorts or units, and for a daily capacity of 1,000 tons per day, which would require four benches of 64 retorts, the cost of this part of the plant should be about £65,000. In actual practice, however, this figure will need to be enlarged.

Thus, Mr. N. M. Henderson stated that a Henderson retort for experimental purposes would cost from £350 to £500 complete; but if these retorts were erected in any considerable number at a plant for retorting shale the cost would be from £60 to £70 per ton of shale put through daily. Such figures refer to the cost of a retort plant erected only on a large scale, and, using such basis of calculation, only an approximate cost of a retort plant would be obtained.

Mr. James Bryson, of the Pumpherston Oil Company, stated that a Pumpherston retort would cost £350 when only one was erected for experimental purposes, and that this figure includes a condenser, ammonia scrubber, and receiving tanks, but does not include the scaffold for charging the top of the retort.

It was further stated by Mr. Henderson that a crude oil plant, the size of that at Tarbrax, with a capacity of 700 to 800 tons daily, would cost about £100,000 in Scotland, this figure including condensers, engines, pumps, shale breakers, tanks, boilers, sheds, all connexions for these, a naphtha recovery plant, an ammonium sulphate plant, and all brickwork necessary. The nominal figure of £65 per ton capacity quoted serves merely as a basis for calculating the cost of the retorts, and does not refer to a complete crude oil plant.

The complete cost of a retorting plant containing 180 Pumpherston retorts would be £80,000. This figure not only includes retorts and accessories, but a naphtha plant, ammonium sulphate plant, steam boilers, brickwork, and all appliances necessary at the crude oil stage.

From Messrs. A. F. Craig and Company, who are very large manufacturers of oil machinery, it was learned that the cost of three benches of 64 retorts each, with all condensers, engines, pumps, tanks, boilers, sheds, and connexions, would be about £43,700. A naphtha recovery plant for the same would be £1,550; an ammonium sulphate plant for the same would be £4,320; and all brickwork necessary for the erection of these plants would be £16,200.

These figures apply only to plants erected in Scotland, and to those portions of the plant necessary at the crude oil stage. They do not include cost of erection and delivery.

The figures at first furnished by Mr. Henderson of £65 per ton of shale put through refer only to the cost of the retorts and not to completely equipped crude oil works, which include a naphtha recovery plant and ammonium sulphate plant.

Mr. Henderson also stated that the cost of a sulphate house, with a capacity of 1,200 tons of shale per day, would be about £5,000; the cost of a refinery plant would be about £11,000 per 1,000,000 gallons, and the cost of a candle house for such a refinery would be from £5,000 to £7,000 complete, in Scotland.

Market Values of Stock.

In order to show the market values of the leading stocks of the principal oil-shale companies, the following data taken from the Edinburgh Daily Stock and Share List for July 30, 1908, may be given. They refer to six of the leading companies in the district, and comprise the Broxburn, Oakbank, Pumpherston, Tarbrax, Youngs, and Dalmeny:—

BROXBURN.

Broxburn, Limited (17s. paid), sold on June 26, 1908, for 44s. 6d., and on July 29, 1908, for 43s. 6d. The highest price in 1907 was 46s., and the lowest 36s., while in 1908, prior to July, it reached 46s. 7·5, but has gone as low as 36s. The dividends for the last half-year amounted to 17·5, while for the previous half-year they were 15.

Broxburn 6 per cent cum. preference (£10 paid), sold on June 26, 1908, for 12⅛, and on July 29, 1908, for 12⅛ (last price). The highest price in 1907 was 12 9/16, and the lowest 12¼, while in 1908, prior to July, this stock reached 12⅜, but went as low as 24⅛. The dividends for the last half-year amounted to 6, and were the same for the previous half-year.

This Company has headquarters in Glasgow, at 28 Royal Exchange square, Mr. W. Love, Managing Director. They were registered November 6, 1877. In 1907, each ordinary share of £10, with £8 10s. paid, was subdivided into 10 shares of £1, and the authorized capital is now £335,000, all of which has been issued, £100,000 in fully paid 6 per cent cumulative preference of £10, with a priority as to capital, and £235,000 in ordinary shares of £1, with £199,750, or 17s. per share paid up. A sum of £10,000 has been borrowed. The accounts are made up annually to about the end of March, and submitted in May,

dividends then declared being paid in equal proportions just after the meeting, and in the following December. For each of the three years to 1897-8, the dividend was 7½ per cent; for 1898-9, 8½ per cent; for 1899-1900, 15 per cent; for 1900-1, 20 per cent; and for each of the six years to 1906-7, 15 per cent. Reserve fund is £50,430; carried forward, £2,504. Voting power, one vote for each ordinary share. Director's qualification, 1,000 ordinary shares.

OAKBANK.

Oakbank, Limited (17s. paid); sold on June 26, 1908, for 39s. 3d., and on July 29, 1908, for 39s. 9d. The highest price in 1907 was 43s., and the lowest 29s.; while in 1908, prior to July, it sold for 42s., but fell as low as 28s. 6d. The dividends for the last half-year amounted to 15, and were the same as for the previous half-year.

Oakbank cum. preference sold for 2s. 4½d. on June 26, 1908. The highest price paid for this stock in 1908 was 2s. 10½d., and the lowest 2s. Dividend for the last half-year was 6.

This Company has headquarters at 39 Vincent Place, Glasgow. Managing Director, J. Wishart. Registered January 7, 1886, to take over the properties of a company of the same name, established in 1869. The shares were formerly £10 each, fully paid, but in 1906 the sum of £1 10s. per share was returned, and the shares were subdivided. The authorized capital is now £200,000, in shares of £1, all of which has been subscribed, and £170,000, or 17s. per share paid up. There are also cash deposits to the amount of £27,549. The accounts are made up annually to March 31, and submitted in May, the dividend then declared being payable in equal instalments soon after the meeting, and in the following November. For 1895-6, 5 per cent was paid; for 1896-7 and 1897-8, nil; for 1898-9, 5 per cent; for 1899-1900, 7½ per cent; for 1900-1, 12½ per cent; for 1901-2 and 1902-3, 7½ per cent each year; for 1903-4, 12½ per cent; and for 1904-5, 1905-6 and 1906-7, 15 per cent. Works insurance reserve fund, £5,000; retort renewal fund, £25,000; carried forward, £4,940. Voting powers, one vote for each share, but no vote for less than ten shares. Director's qualification, £500 nominal of shares held in own right.

PUMPHERSTON.

Pumpherston, Limited (17s. paid); sold on June 26, 1908, for £13 5s., and on July 29, 1908, for £12 15/16. The highest price in

1907 was 14, and the lowest 6⅝, while in 1908, prior to July, it sold for 13½, but fell as low as 11⅝. The dividend for the last half-year amounted to 50, and was the same for the previous year.

Pumpherston 6 per cent cum. preference (£10 paid) sold on June 26, 1908, for 13, and on July 29, 1908, for the same price. The highest price so far this year has been 13¼, and it has never fallen below 13 this year. The dividend for 1907-8 amounted to 6.

This Company was registered November 3, 1883, to acquire certain properties on leases for 31 years. Headquarters, 135 Buchanan street, Glasgow. Managing Director, Mr. W. Fraser.

The authorized capital is £230,000—£100,000 in 6 per cent cumulative preference shares of £10, with a priority as to capital, and £130,000 in ordinary shares of £1. All the shares have been issued (the preference in 1890), and £210,500 paid up, the preference shares being fully paid, while the ordinary have 17s. paid. The ordinary shares were originally of £10, but in 1905 they were subdivided into denominations of £1. They were formerly debentures, but these have now been paid off. The accounts are made up annually to April 30, and submitted in May, and the dividend then declared on the ordinary shares is usually paid in equal instalments in June and December after the meeting, the dividend on the preference shares being paid annually in June. For 1894-5, and 1895-6, the ordinary shares received 5 per cent each year; for 1896-7, no dividend on either class of shares; out of the profits of 1897-8 the preference dividend was paid for 1896-7; out of the profits of 1898-9, 9 per cent was paid on the preference shares; for 1899-1900, the preference shares got 9 per cent (thus clearing off arrears), and the ordinary got 20 per cent; for 1900-1, the ordinary got 15 per cent; for 1901-2, 7½; for 1902-3, 20; for 1903-4, 1904-5 and 1905-6, 30; and for 1906-7, 50. Reserve fund, used in the business as working capital, £80,000; fire insurance fund, £5,000; carried forward, £6,180. Voting powers, one vote for each ordinary share, held for three months; the preference shares carry no voting rights. Director's qualification, 1,000 ordinary shares.

TARBRAX.

Tarbrax, Limited (£1 paid); sold on June 26, 1908, for 59s. 9d., and on July 29, 1908, for 56s. 6d. The highest price in 1907 was 65s. 6d., and the lowest 32s., while in 1908, prior to July, it reached 63s. 9d., and has not fallen below 53s. 9d. The dividend for the last half-year was 15.

Tarbrax 6 per cent cum. preference (£1 paid) sold on July 29, 1908, for 22s. 6d. The dividend for the year was 6.

Tarbrax Oil Company, Limited, head office, 135 Buchanan street, Glasgow, W. Fraser, Chairman, was registered June 15, 1904, to acquire leases of the shale, etc., in certain lands in the counties of Lanark and Midlothian. Authorized capital, £150,000, in shares of £1, £50,000 being in 6 per cent cumulative preference shares, having a priority also as to capital, and £100,000 in ordinary shares, and £40,000 preference, and £65,000 ordinary have been subscribed and paid up, 5,000 preference and 6,000 ordinary shares having been issued to the vendor, the former fully paid and the latter with 17s. per share credited as paid. There are also loans for £31,762. The accounts are made up annually to April 30, and submitted in May or June. For the year 1906-7 there was a credit balance of £9,757, out of which the preference dividend was paid for the period from the date of incorporation to April 30, 1907, absorbing £5,191, leaving £3,542 to be carried forward. Voting powers, one vote for every share of either class, but preference shareholders only one vote under special conditions. Director's qualification, 500 shares of either class.

YOUNGS.

Young's Paraffin Light, Limited (£4 paid); sold on June 26, 1908, for 80s. 6d., and on July 29, 1908, for 73s. The highest price in 1907 was 81s., and the lowest 65s., while the highest price this year so far has been 81s. 6d., and the lowest 66s. The dividend for the last half-year was 7, and for the previous half-year, 6.

Young's 6 per cent 'B' mortgage bonds (£100 paid) sold on June 26, 1908, for 196. The highest quotation in 1907 was 180½, and the lowest 162, while so far this year the highest has been 197½, and the lowest 160½. The dividend for the last half-year amounted to 22, and for the previous half-year was only 6.

Young's Paraffin Light and Mineral Oil Company, Limited, with head office at 7 West George street, Glasgow, Mr. J. Fyfe, Managing Director, was registered January 4, 1866. At the close of 1883 it absorbed the Uphall Oil Company, Limited. In 1887, the sum of £6 per share was written off the capital, which now consists of £700,000 in shares of £4, of which £452,808 has been allotted and called up. There are also 5 per cent ninety-nine year 'A' mortgage debenture bonds for £126,800 (issued mainly in 1896 to replace short-dated

bonds, etc.) secured as a first charge (equally with the ninety-nine-year bonds, 1894 issue) upon the heritable properties, and redeemable by ballot at 10 per cent premium at any time on six months' notice, the interest dates being February 1 and August 1; ninety-nine-year 6 per cent mortgage debenture bonds, 1894 issue, for £23,200, secured as a first charge (equally with the 'A' bonds) upon the heritable properties, and redeemable on six months' notice at any time at a premium of 10 per cent, the interest dates being May 1 and November 1; and 'B' debenture bonds for £150,000 (issued in 1890 to replace short-dated bonds, etc.) secured as a second charge on the heritable properties, and repayable August, 1995, the interest dates being February 1 and August 1 (interest at 'a minimum rate of 6 per cent, with a further contingent right to interest equal with the said 6 per cent to twice the dividend payable on an equal amount of ordinary share capital').

The accounts are made up annually to April 30, and submitted in June, and the dividend then declared is paid in equal proportions soon after the meeting and in the December following. For several years there was no dividend; but for 1900-1, 3 per cent was distributed; for 1901-2, 2½ per cent; for 1902-3, 3 per cent; for 1903-4, 5 per cent; and for 1904-5, 1905-6 and 1906-7, 6 per cent each time. The 'B' debentures had been getting 6 per cent per annum up to 1902-3, but for 1903-4 they got 10 per cent, and for 1904-5, 1905-6, and 1906-7, 12 per cent each time. Fire insurance fund £15,000; carried forward £8,510. Voting power, one vote for every 5 shares up to 100, and an additional vote for every 10 shares beyond the first 100. Director's qualification, 200 shares.

DALMENY.

Dalmeny, Limited (£7 paid), sold on July 29, 1908, for 5½. Dalmeny 5 per cent preference (£7 paid), sold on July 29, 1908, for 93s.

Dalmeny Oil Company, Limited. Managing Director, A. Jones. Office, Dalmeny, Edinburgh. Company registered October 20, 1871. Late in 1896 it was decided to reconstruct, and the present Company was registered November 26, 1896. The authorized capital is now £64,800, £18,900 being preference or 'A' shares of £7, ranking for non-cumulative dividends of 5 per cent per annum, and having a priority as to capital; and £45,900 ordinary 'B' shares of £8 10s. The entire capital has been subscribed, the preference shares being fully paid and the ordinary shares having £7 per share called

up. The accounts are made up annually to the end of October, and submitted in January. For 1896-7, the new Company paid 7½ per cent on the ordinary shares; for 1897-8, 5 per cent; for 1898-9 and 1899-1900, there was no dividend on either class of shares, owing largely to the workings having been flooded in the former year; for 1900-1 and 1901-2, the ordinary shares received 5 per cent per annum; for 1902-3, 7½ per cent; for 1903-4, and for 1904-5, 10 per cent; and for 1905-6, 2½ per cent. Carried forward, £846. Voting power, one vote for every share of either class. Director's qualification, 50 shares of either class held in own right.

The Commercial Value of Oil-shale.

The commercial value of the oil-shale can be best inferred from a study of the prices and quantities obtained by distillation. Thus in the case of the shipment made from New Brunswick as per results already stated, the yield of crude oil was found to be 40 gallons imperial, or 48 United States gallons, and of sulphate of ammonia 77 pounds. These, it may be mentioned, are practically the two most valuable substances obtained from the first distillation. A further series of distillations, or fractionations, will give other valuable by-products, but for the present the conditions attending the production of the crude oil and sulphate of ammonia may suffice, since for these two sufficient data is now available to form a fair estimate of the cost of manufacture, the value of the shales, and the possible profits to be expected from their manufacture. It is also doubtful at the present time if an expensive plant for the manufacture of refined oils, paraffins, naphthas, etc., on a large scale, would, in the face of possible competition and hostility on the part of the Standard Oil Company in this country, be sufficiently profitable to warrant the necessary expenditure of capital in this part of the proposed enterprise.

Assuming then the value of crude oil at present prices, per barrel, to be 0·025 per gallon, and of sulphate of ammonia, at £12 per ton, as $0·029 per pound, we have as the value of the shale tested in Scotland in 1908:—

48 United States gallons crude at 0·025.	$1 20
77 pounds sulphate of ammonia at 0·029	2 23
Bonus from government at 1½ cts. per gallon. .	72
	$4 15

Similarly, taking the figures of contents in crude oil and sulphate of ammonia as furnished in the table of analyses given by Dr. Baskerville already stated, and allowing values of \$0·025 per gallon for crude, and \$0·029 per pound for the sulphate of ammonia, and the government bonus of 1½ cents per gallon on all shale obtained by the distillation in each case, we have the following results as to commercial values of the shales from several localities:—

Locality.	Gals. per ton.	Lbs. Sulph. Ammon.	Values.	Bonus.	Totals.
			\$ cts.	\$ cts.	\$ cts.
Baizleys............	65 x 0·025	110 x 0·029	4 81	0 92	5 73
E. Stevens..........	59 x 0·025	67 x 0·029	3 41	0 88	4 29
Haywards..........	30 x 0·025	75 x 0·029	3 04	0 45	3 49
Adams farm.........	51 x 0 025	93 x 0·029	3 96	0 76	4 72
Taylors farm, No. 1.	58 x 0·025	98 x 0·029	4 29	0 87	5 16
Taylors farm, No. 2.	44 x 0·025	110 x 0·029	4 29	0 66	4 95

From these totals the sum of \$1.86 may be deducted in each case as representing the cost of mining, retorting and manufacturing the sulphate per ton of shale:—

Mining the shale per ton................	\$1 00
Retorting the shale per ton..............	40
Manufacture of sulphate................	46
	\$1 86

This should give only an approximate profit from each seam of shale tested, since no allowance has been made for interest on invested capital.

General view of Broxburn Refinery, showing the Paraffin House in the rear, and offices in front, Broxburn, Scotland.

APPENDIX.

THE TECHNOLOGY OF THE SCOTTISH SHALE OIL INDUSTRY.*

BY

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GENERAL DESCRIPTION OF A SHALE OIL PLANT.

The Crude Oil Works.

The crude oil works consist of retorts, arranged in benches, the necessary condensers and scrubbers, the naphtha recovery plant, and the ammonium sulphate plant. The shale as it is received at the mine head is transferred to the retort department of the works by means of wagons, which are emptied into the shale-breakers by hydraulic machinery, and there the shale is broken into small pieces, about 6″ square, by passing it between two toothed drums or rolls, about 9 feet long, which are driven by gearing from a steam-engine. The breakers are made of cast-iron discs, about 3 feet in diameter, and are provided with heavy teeth on their periphery. The tooth clearance is about 1″. Each breaker crushes about 200 tons of shale per day of eight hours, and there is one or more of them, according to the amount of shale required (Plate X). From the breaker, the shale drops into iron hutches, holding from 10 to 25 cwts. each, which are hauled up an incline to the top of the retort bench. The hutches are raised by an endless chain (Plate XIII) set in motion by wheels geared from the engine which runs the breakers, and are so constructed that they are easily tipped for discharging into the top of the retorts. Four labourers, each receiving four shillings per day, are required for each breaker.

The crude oil works are generally located in the centre of the shale fields, and in this way considerable expense is saved in haulage.

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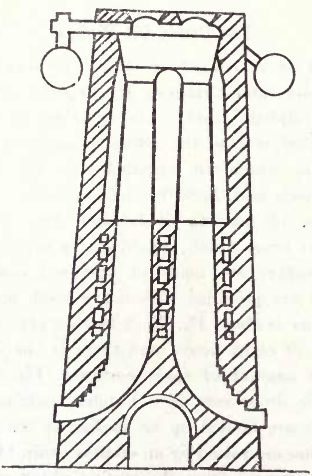
* Published by permission of Dr. Charles Baskerville, Director of the Chemical Laboratories, College of the City of New York.

(*a*) RETORTS.

Oil-shales, bituminous shales, and coals do not contain free oil or oily matter—that is, they are not oil-bearing—but must be subjected to destructive distillation at low temperatures, in order to obtain a crude oil from them. This distillation is carried out in retorts, of which many forms have been devised. At the present time, however, there are four types of retorts in operation, viz., the Pumpherston, the Henderson, the Young and Fyfe, and the Crichton. All of these retorts are based on the Young and Beilby principle.

The Young and Beilby retort (Fig. 1) which was patented in 1881, consists of four iron retorts, connected with a common hopper above. Each retort is provided with an iron upper part in which the

Fig. 1.



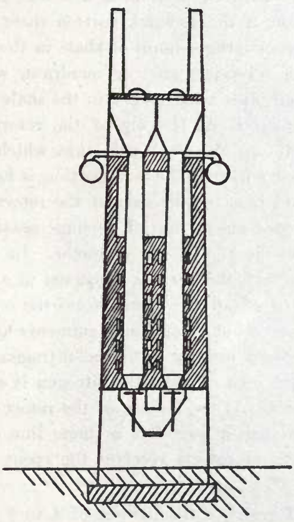
Young and Beilby Retort.

oil is distilled from the shale at the lowest possible temperature (*circa* 900° F.); and, after the oil is practically all distilled, the shale passes down through the lower portion of the retort, which is built of firebrick. In this section of the retort the shale is subjected to a high temperature (*circa* 1300° F.) in the presence of steam, thereby converting the carbon into a mixture of carbon dioxide and carbon monoxide, and the nitrogen of the shale into ammonia. About

one pound of steam per square foot of shale is used, and the shale remains in the retort for eighteen hours. Every six hours about 8 cwts. of broken shale is put in the top hopper (jumbo), and at the same time the spent shale is removed from the bottom hopper. A bench of 80 Young and Beilby retorts distills 100 to 120 tons of shale per twenty-four hours. In 1894, the quantity of shale distilled in retorts of this type amounted to 92 per cent of the production of Scotland. During this year 1,986,300 tons of oil-shale were mined. The cost of retorting one ton of shale in retorts of this principle was 24d.

The Pumpherston, or Bryson retort (Eng. Pat. 7113, 1895) (Fig. 2) was devised by Messrs. Bryson, Jones, and Fraser, and is used by the Pumpherston, Oakbank, Dalmeny, and Tarbrax companies

FIG. 2.



Bryson Retort.

with great success. It has been in use on an extensive scale since 1896, and there are now 1,130 retorts on this principle in operation in Scotland, with 272 additional retorts in the course of erection. The experimental retort erected by Mr. James Bryson at the Pumpherston works, in 1894, was the first constructed on this plan. It was found that, in addition to reducing the cost of working by

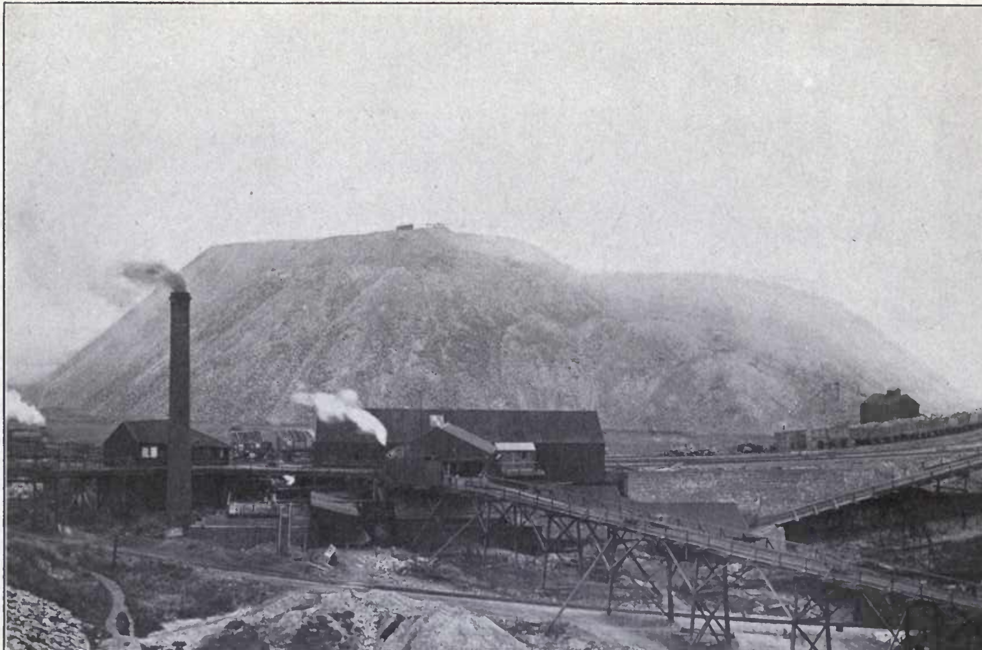
one-half, as well as improving the yields got from the shale, it removed the difficulties and heavy losses caused by the shale fluxing in the older types of retorts, which were only moved intermittently, the continuous moving of the whole mass of shale in the new type preventing the fluxing, reducing the up-keep from a heavy charge to a nominal figure, and prolonging the life of the retort to an extent as yet undetermined, as the first bench built, in 1896, is still being worked to its full capacity.

The Pumpherston retort consists of two portions: the upper or cast-iron portion, which is 15 feet in length, 2 feet in diameter at the top, and 2′–4″ in diameter at the bottom; and the lower or firebrick portion, which is 20 feet in length, 2′–4″ in diameter at the top, where it joins the cast-iron portion, and 3 feet in diameter at the bottom. At the end of the firebrick portion there is a disc support, or table, which supports the column of shale in the retort; this table is provided with a revolving arm, or quadrant, which removes the spent shale and maintains a movement in the shale column by revolving at regular intervals. At the top of the retort there are iron hoppers, holding 4 tons, 10 cwt. each, into which 1 ton of broken shale is charged every hour. The iron portion is heated to a dull red heat externally, and it is in this part of the retort that the destructive distillation takes place, the oil vapours passing out below the hoppers in an iron main, 2′–6″ in diameter. In the lower, or firebrick part of the retort, the shale is subjected to a temperature sufficiently high to burn off all the carbon from the oil-spent shale; this is done in the presence of steam, and ammonia is produced by the hydrogen of the steam uniting with the nitrogen contained in the shale. About 60 per cent of the total nitrogen is converted into ammonia and recovered. At the bottom of the retort there are hoppers, which converge in such a way that a single line of rails under the centre of the bench of retorts receives the spent shale, in an iron hutch, 5 feet x 4′–6″ x 2 feet.

In this type of retort, a throughput of 4 to 5 tons per day may be worked at a cost not exceeding 1s. 6d. per ton.

The cost of the Pumpherston retort, including condenser, ammonia scrubber, and receiving tanks, but exclusive of the scaffold for charging, amounts to £350.

The men necessary for the operation of retorts of this type receive the following wages:—



Breaker house, showing trams from mine and to retorts. Heaps of spent shale in rear, Broxburn, Scotland.

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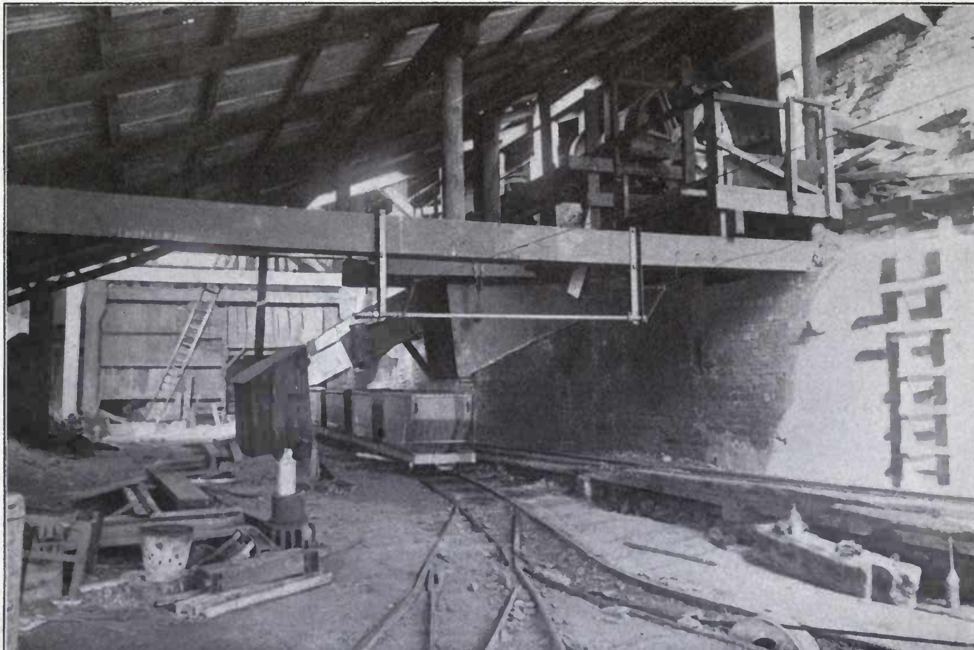

Discharge from breaker, Broxburn, Scotland.

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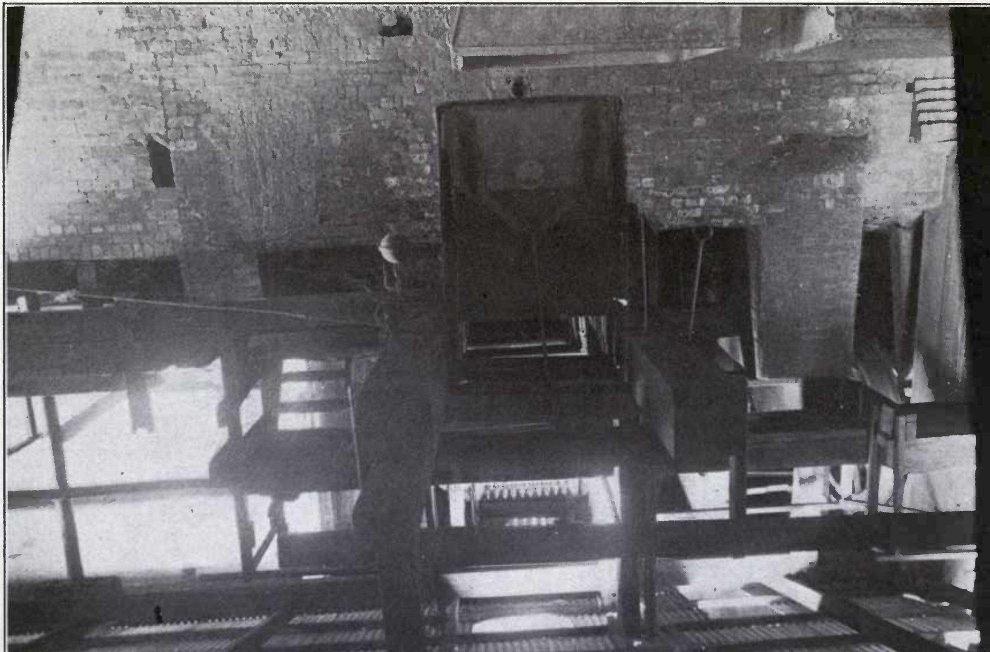


Discharge from bottom of breaker, showing pair of toothed rolls, Broxburn, Scotland.

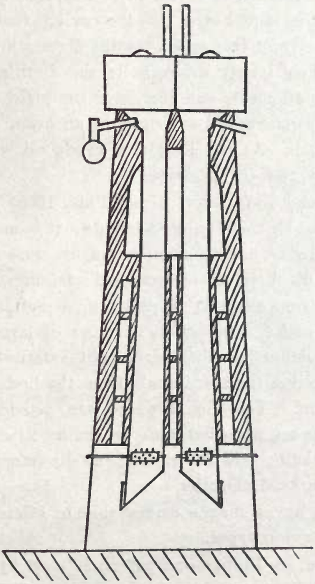
5656—p40³

Foreman of 3 benches..	£2 10s. per week.
Two assistants..	£1 18s. "
Dropper for 1 bench..	5s. 4d. per day.
Charger for 1 bench..	5s. 4d. "
Tipman for 1 bench..	6s. "

These men work seven hours per day. The foremen get free house rent, light and heat.

The Henderson retort (Eng. Pat. 6726, 1889) (Fig. 3) is now used by the Broxburn Oil Company, Limited, in an improved form (Eng. Pat. 26647, 1901). This type of retort is 60 feet high from the ground-level to the top of the upper hopper, and the section is oblong.

Fig. 3.



Henderson Retort.

The metal part is 2′–6″ x 1′–2″ at the top, and the brick part is 3′–8″ x 1′–10″ at the bottom; the metal part is 12 to 15 feet in length, and the brick part is 19 feet long. In its newest form, the Henderson

retort has two toothed rollers, 3′–6″ in length at the bottom to support the shale column and to maintain a downward movement of the shale, thereby regulating the speed of the discharge of spent shale into the hopper below. The original form of this type was provided with a single delivery roller and was smaller; it put through 35 cwts. of shale per 24 hours, while the 1901 retort is capable of retorting 4½ tons per 24 hours.

Each retort is provided with a malleable-iron hopper on the top, having a capacity of 54 cubic feet and capable of holding 18 hours' supply of shale. The products are conducted off in a 2 ft. branch pipe at the bottom of the top hopper.

The retort is heated by gas made from dross coal, in Wilson gas producers, which method is found to be advantageous in manipulating and regulating the heats, besides saving fuel. The increased length and capacity of this type over the Young and Beilby resulted in giving the shale longer exposure to the distillation temperature, diminished wear and tear, and increased the yield of ammonia.

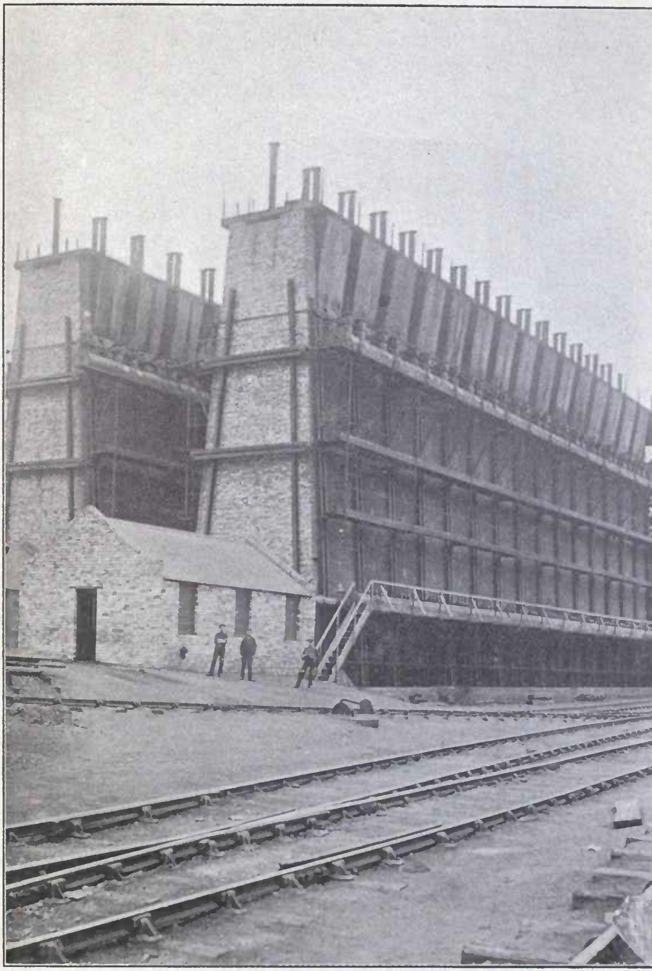
Four of these retorts are arranged in an oven, and sixteen ovens constitute a bench. At the Broxburn crude oil works, three and a half benches are now in operation.

The Young and Fyfe retort (Eng. Pats. 13665, 1897; and 15238, 1899) is now used by the Young Company; it is merely a remodelled Young and Beilby type, as the improvements were applied to the old retorts in use. Each retort is composed of four sections, namely, a hopper redistillation chamber at the top, a metallic section, a firebrick chamber, and a combustion chamber of large capacity at the bottom. The combustion chamber is not externally heated, as the rest are, but receives the spent shale from the firebrick chamber in a red-hot condition. The top hoppers are provided with rocking shafts, to which are attached rods or chains to ensure the regular passage of the shale; and the continuous discharge at the bottom is maintained by a kind of roller.

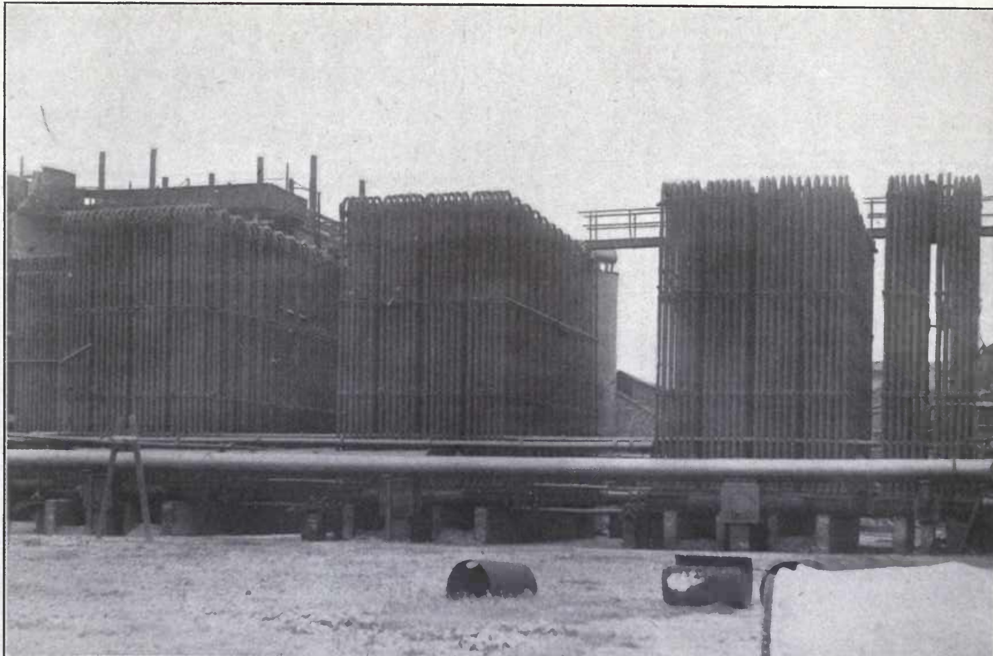
This type is by no means comparable in efficiency to either the Henderson or Bryson types.

The Crichton, or Philipstoun retort, is used by James Ross and Company, at Philipstoun. It is built on the principle of the Young and Beilby retort; and consists of 18′–3″ of brickwork and an iron part 10 feet in length.

As in the case of many of the shale retorts that have been designed, this type differs from the others mainly in the mechanical



Bench of Retorts, Broxburn Works, Scotland.



Condensers, Pumpherston Works, Scotland.

appliance at the base of the retort for removing the spent shale. This appliance consists of two transverse shafts which work into a plain boss at the back of the hopper, and pass through an easy-working stuffing-box at the front to the outside of the bench of retorts. The outer ends of the shafts are carried on an iron bearer with cod and coyer, and on the end of each shaft there is an arm connected with links to a hand-lever. Each shaft is fitted with a set of grippers, and the discharge of spent shale is regulated by their manipulation.

The retorts are drawn every six hours, and the throughput is about the same as in the old Henderson retort. The shale in the retort is under perfect control, but such a type is much more expensive and would not pay on a large scale.

(*b*) RETORT CONDENSERS.

The oil and water vapours leave the retorts by an outlet pipe, usually about 8″ in diameter, and enter a common main, generally about 30″ in diameter. This main conveys the gases into a water heater, a tower in which water for the steam boilers is heated in pipes, and then into large upright air-cooled condensers, formed of light cast-iron spigot and faucet pipes, 4″ in diameter, fitted with cast-iron chests and resting on them (Plate XII). Two hundred feet of condenser pipe are required for every ton of shale put through per 24 hours. The crude oil and ammonia water collected from the condensers are run into a separator, where they are separated, while the uncondensible gases pass into exhausters, which continually maintain a slight pressure on the retorts. The gases then pass into a vertical water-scrubber, where the last traces of ammonia are removed; and next into a naphtha scrubber, where the gas is washed with mineral oil to absorb the naphtha. These scrubbers are generally 5 feet in diameter and 30 feet in height.

The efficiency of tower scrubbers for removing ammonia and light hydrocarbons from the uncondensible retort gases depends on three factors: the height of the towers; the extent to which the vapour is split up in its passage through the vessels; and the regular distribution of the absorbing material, which is now generally wooden chequer work, although coke was used for many years. The theoretical scrubbing limit is never attained in the ammonia scrubbers; the practical limit is reached when the gas contains not more than 0·5 grain of ammonia per 100 cubic feet; and about three pounds of

ammonium sulphate per ton of shale put through is recovered. In the naphtha scrubbers it is possible to reduce the illuminating power of the uncondensible gas to about one-half a candle. An intermediate oil (sp. gr. 0·84 to 0·856) is used for scrubbing, and about two gallons of light spirit (0·73) are recovered from the scrubbing oil per ton of shale put through the retort.

The number and size of these towers is dependent on the number of retorts in operation; but for three benches of retorts (192) three naphtha scrubbers and two ammonia scrubbers are necessary.

The scrubbing oil is denuded of naphtha by steaming it in a vessel containing a series of plates and cups with corrugated edges. The denuded mineral oil is used continuously after cooling.

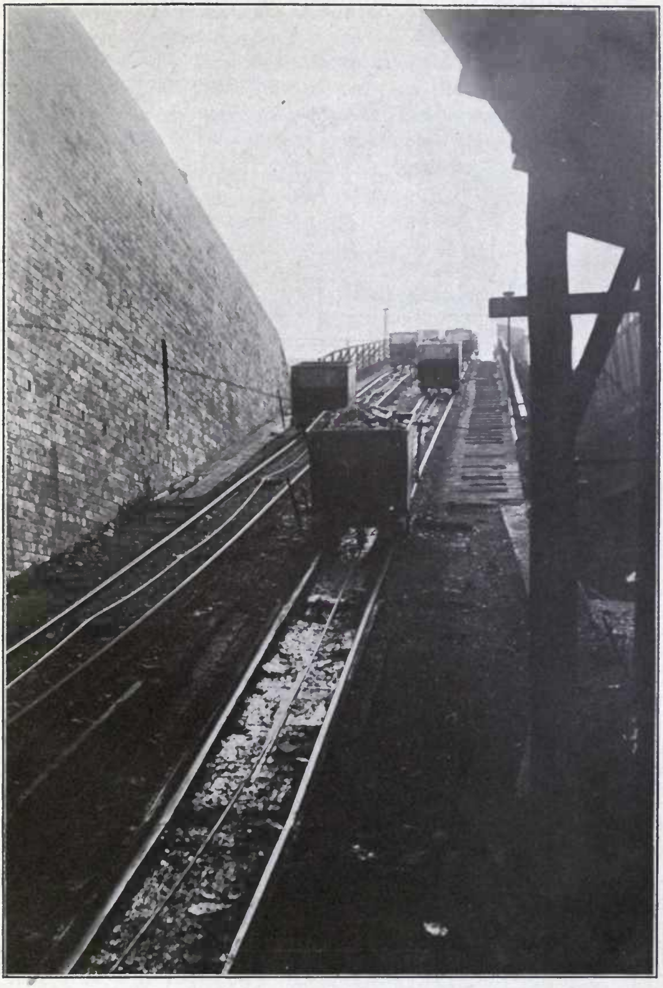
After the retort gas is freed from all condensible and absorbable matters, it is caught by a fan, which forces it under a few inches pressure into the main which supplies the burners at the bottom of the retort flues.

It will be seen that the results of the distillation of shale in retorts are as follows: (1) Spent shale, which is removed from the bottom hoppers and conveyed by mutches to the dumps; this residue is of no value, although it has been used in brick-making, road-making, and has been suggested as a material for the manufacture of alum. Spent shale contains about 2·5 per cent of fixed carbon, and is essentially an aluminium silicate; 80 to 85 per cent of the raw shale put into the retorts is sent to the waste heaps as spent shale. (2) Permanent gas, which is used as fuel in the retorts. (3) Crude oil, which is pumped into tanks and then refined. (4) Naphtha, which is recovered as above described. (5) Ammonia water, which is distilled for the manufacture of ammonium sulphate.

(c) AMMONIUM SULPHATE PLANT.

It was some time after the distillation of shale had been started in Scotland before the value of the water from the retorts was discovered. Robert Bell, of Broxburn, ascertained its value in 1865, and placed ammonium sulphate on the market in May of that year.

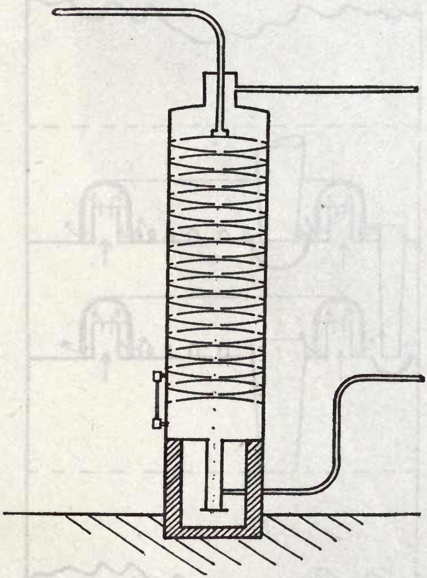
Stills.—The method which was first used for expelling the ammonia from the ammonia water was to boil the latter in horizontal boilers and conduct the gas into vessels containing sulphuric acid, called cracker boxes. It was found, however, that considerable loss of ammonia occurred from the inability to drive off all the ammonia contained in the water, and in 1882 tower stills were introduced.



Endless tram conveying shale from breakers to retorts, Broxburn, Scotland.

The Beilby ammonia column-still was patterned after the Coffey alcohol still, and was the first tower still used. In this still, the ammonia water entered at the top and was deprived of most of the ammonia, before it overflowed through an outlet at the base of the still, by the action of 20 pound pressure steam, which passed upwards and carried the ammonia vapours with it. The descending water and the ascending steam were forced to travel over a zig-zag course, and

FIG. 4.



Beilby's Ammonia Column Still.

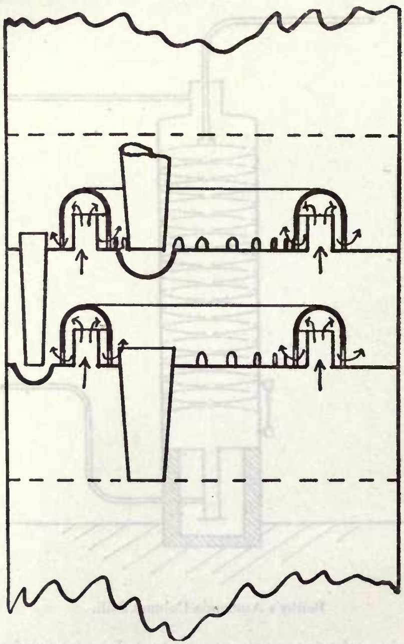
were thereby brought into intimate contact, by means of concav and convex plates containing openings. The action of this still was continuous (Fig. 4).

Nearly all the ammonia stills now in operation are based on the Henderson type (Eng. Pat. 15836, 1885). In this column-still the ammonia water is run in at the top, and runs from tray to tray, where it is acted on by 30 pound pressure steam, blown in at the

bottom of the still. The ammonia water is consequently boiled, and the volatile ammonia compounds are expelled in a gaseous state. The stills of this type are generally 22 feet in height, and 5 feet in diameter, and contain 11 trays (see Fig. 5). The capacity of such a still is 45,000 gallons of ammonia liquor per diem.

The gaseous ammonia compounds are passed into sulphuric acid: first into sulphuric acid recovered from the refinery tars, the

FIG. 5.



Two Trays of Henderson Ammonia Column Still.

ammonium sulphate thus produced being obtained by boiling down the solution; and second, the rest of the gas is passed into a cracker box of fresh chamber sulphuric acid. Wilton's form of cracker box is now widely used. The sulphuric acid flows in the cracker box in a constant stream in lead pipes, with perforations in

"Bings" or heaps of spent shale, with tramway from retorts to summit, Broxburn Works, Scotland.

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the part laid along the bottom, where it meets the ammonia gas. The cracker boxes are cylindrical tanks made of ¼″ iron, and are lined with 10 pound lead sheet. The ammonium sulphate forms by the interaction of the sulphuric acid with the ammonia gas, and falls along the sloping bottom into a well, from which it is raised by a steam injector and thrown into a receiving box. The crystals are then transferred to draining tables and afterwards to a drying room, where they are exposed to a temperature of 100° to 120° F. for several days. At several of the works centrifugal dryers are being used with great success.

In diluting the acid used, the solution of ammonium sulphate made from the recovered acid is generally run in, thereby saving a separate evaporation of it. The fixed ammonia in the ammonia water from the retorts (about 1 pound per ton of shale) is recovered by distillation over lime, which is accomplished by putting lime into the stills.

An ammonium sulphate plant with a capacity of 1,200 tons per day costs £5,000, and the cost of manufacturing one ton of ammonium sulphate is £2 5s. The cost of the sulphuric acid used in manufacturing one ton of sulphate is 25s., and this is generally purchased, the Broxburn Company being the only one which manufactures all their own acid. The sulphate men receive a wage of 4s. 6d. per day of eight hours.

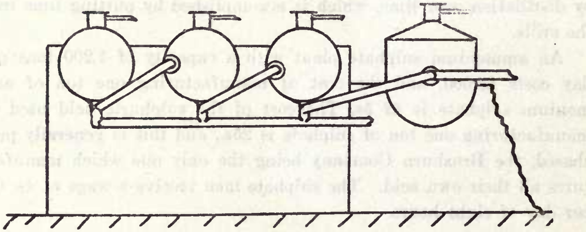
The Refinery.

Crude shale oil is of a dark green to a brownish colour, possesses a specific gravity of 0·86 to 0·96, and has a congealing point of approximately 32° C. It is substantially a mixture of the paraffin and olefine series, with a small amount of naphthenes, benzines, and alkaloidal bases; and contains about 1 per cent of nitrogen. The quality of the crude oil depends greatly on the temperature at which it is formed from the kerogen, or bituminous matter, in the shale. It has been ascertained that the greater part of the decomposition and distillation in the retorts occurs below 427° C., and upon investigation it seems probable that 554° C. is the maximum temperature required in a retort, as this temperature is the highest boiling point of any normal paraffin; and as oil-shale produced in Scotland is of a paraffin base, steam is necessary in the iron portion of the retorts, just as it is in the firebrick part, and its presence prevents decomposition.

Four companies are now refining crude shale oil in Scotland, viz., the Pumpherston Company, which refines the crude product of the Pumpherston main plant, the Seafield and Deans works, and the crude oil of the Tarbrax Company, and a portion of the oil of the Ross Company; the Oakbank Company, which refines its own product as well as that of the Dalmeny Company; the Young Company; and the Broxburn Company, which refines the crude oil produced at the Broxburn crude oil works and at the Roman Camp Works.

Oil-shale refineries consist of (*a*) stills for distilling the crude oil and refining the fractions (Fig. 6); (*b*) agitators and settling tanks, in which the oils are treated with sulphuric acid and caustic soda for the separation of the tarry matters; (*c*) paraffin-house,

FIG. 6.



Connected Boiler Still.

where the heavy oil obtained from the crude oil is cooled and pressed for the separation of the paraffin wax; (*d*) paraffin refinery, where the wax is refined; (*e*) stock tanks for the finished products; (*f*) shipping department, where the barrels are made and the products are shipped to the consumers; (*g*) candle-house, where the paraffin is made into candles for the trade; and sometimes (*h*) a sulphuric acid manufactory, where the sulphuric acid required for refining, and the production of ammonium sulphate is made, and concentrating plants. There are also, of course, shops, saw-mills, offices and laboratories. All are arranged with due regard to convenience, cheapness, and safety from fire.

(*a*) REFINERY OPERATIONS.

After being settled from ammonia water and shale dust in the separators, the crude shale oil is pumped into charging tanks, from

View in Refinery, Broxburn Oil Works.

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which the oil may flow by gravity into the refinery stills. There are high charging tanks behind each bench of stills, and low tanks to receive the distillates.

The crude oil is first once run, that is, it is first distilled to dryness, separating into naphtha and once run oil, which is then refined further. The crude oil is not treated directly with sulphuric acid and caustic soda, as the loss would be great, but is subjected to destructive distillation at once, whereby the tarry matters are converted into the required hydrocarbons. This distillation is carried out in pot stills of 2,000 gallons capacity, made of cast-iron, which stills are 3′-6″ to 4′-6″ deep, and 8′-6″ in diameter at the top; the top, which is made of steel, is generally 8′-8″ in diameter x 6 feet in depth. Each still has a condensing worm 225 feet in length, made of 4″ cast-iron pipe immersed in water in a tank. Before the distillate passes from the condenser to the receiver it is conducted into a separator box, which is provided with a water-outlet at the bottom and an oil-outlet higher up. In this box the water resulting from the condensation of the steam used in the distillation is separated from the oil distillate. The stills are first heated externally for about 10 hours, to expel all the water contained in the oil, then steam is gradually introduced. The steam used is more or less superheated, and it serves to prevent decomposition, to carry the oil vapours over, and to lower the boiling point of the oil. The quantity of steam used is variable, but when the heavier oils are distilling off, the distillate is usually accompanied by 20 per cent of condensed water. The crude oil is run down to dryness in about a day, and the steam is not shut off until about three hours after the close of the distillation. The still is then allowed to cool for a day, and the still coke is removed; this material represents about 3 per cent of the crude oil. The pot stills are run about three times per week. The naphtha, which is collected during the first stage of this distillation, has a specific gravity of about 0·74; and the remainder of the distillate is run into one tank and is known as once run oil. There is also some permanent gas produced in this distillation; it is used for fuel. The Broxburn Company have arrangements at their refinery whereby the uncondensible gases from the condensers connected with the crude oil boilers and crude oil residue stills are collected and used. The gases from the residue stills are mostly due to the decomposition of a part of the oil; these gases do not condense to a liquid form under working conditions, but are of value either as illuminants or as fuel. The

Broxburn Company now obtain about 60,000 cubic feet of good illuminating gas per day, or about 1¼ cubic feet for every gallon of crude oil put through. This gas is used for lighting the works and village nearby, which were formerly supplied with gas from coal carbonizers. This Company also obtains about 150 gallons of light naphtha daily by the friction of the gas through a water lute, and it is made into motor spirit. This naphtha comes over with the overflow water of the hydraulic main, and is separated in an ordinary separator and collected in a receiving tank.

In refining oil-shale, noxious gases are evolved. From the condensers connected with the crude oil stills, hydrogen sulphide escapes, and during the subsequent refining and fractionations gases containing hydrogen sulphide are also formed, especially in the residue stills. At the present time the Young's Company use iron oxide purifiers for absorbing the hydrogen sulphide, and find them very successful.

In the distillation of 50,000 gallons of crude oil for the production of once-run oil, 24 pot stills and 5 boiler stills are required. The latter are made of steel, and are for continuous working alone; they are generally 30 feet long and 8′–6″ in diameter. Boiler stills require a condensing area of 850 square feet. In the Henderson system of continuous distillation (No. 540, 1883), the boiler stills are 19 feet in length and 7 feet in diameter. The methods of continuous refining now in use are based on this system.

The once-run oil from the crude oil distillation is first settled free from all moisture, and is then pumped into an acid agitator, where it is treated with sulphuric acid for the removal of the acid tar. The agitator is first charged with the oil and agitation is started, then the acid is added and the agitation is continued for a period of from 15 minutes to over an hour, depending on the grade of the oil. The mixture is then allowed to settle for about a day, and the tar is drawn off at the bottom. The oil is then pumped from the acid agitator into the soda agitator, where it receives the soda treatment. It is allowed to settle for about eight hours after the second treatment with soda, and is then pumped to a storage tank to supply the first stage oil stills. The agitation is performed by means of air in an agitator, from 6 to 9 feet in diameter and 10 to 15 feet in depth. The air is blown in under a pressure of from 6 to 10 pounds per square inch, and serves to mix the oil and acid and oil and soda thoroughly in its passage to the surface.

As above mentioned, the naphtha or spirit is alone separated in

the crude oil distillation, and the remainder of the once-run oil is distilled in the first stage oil stills; it is called green oil, and is fractioned into naphtha, light oil, heavy oil, and heavy oil and wax. The residuum is coked in pot stills. In a refinery having a working capacity of 50,000 gallons of crude oil, 17 pot stills and 6 boiler stills are used at this stage. The light oil and heavy oil are pumped into separate agitators, and are treated with sulphuric acid and soda for the removal of the acid and basic tars.

The heavy oil resulting from the above distillation is then distilled in boiler stills, fractioning into burning oil, gas oil, and heavy oil. The latter is added to the heavy oil and paraffin from the first stage distillation, while the gas oil is cooled and pressed in the paraffin house to separate into soft paraffin and 0·850 gas oil. The burning oil is treated with sulphuric acid and caustic soda, and is distilled along with the light oil distillate of the first stage, fractioning into naphtha, burning oil (0·785), burning oil (0·800), burning oil (0·810), and gas oil. The latter is combined with the gas oil from the heavy oil distillation. The heavy oil and paraffin are cooled and pressed in the paraffin house (see below), producing blue oil and hard paraffin scale. The former is refined with sulphuric acid and caustic soda, and is then distilled over caustic soda in boiler stills, fractioning into lubricating oil. The first lubricating oil distillate is cooled and pressed, giving 0·865 gravity oil and soft wax; and the second distillate is given the same treatment, which results in 0·885 gravity oil and soft wax. The lubricating oil is then refined in pot stills holding 2,200 gallons, and the soft paraffin wax is added to the sweatings from the hard paraffin scale produced from the heavy oil and paraffin. The sweatings are re-sweated, forming 100° m.p. wax and 110° m.p. wax, and the wax from the re-sweating of the hard scale gives 115° m.p. wax, and hard wax. The naphtha from the towers connected with the condensers of the retorts is mixed with the naphtha from the first stage stills, and is treated with acid and soda in agitators provided with means for mechanical agitation. It is then distilled into 0·730 and 0·740 naphtha, and a residue of light oil, which is generally refined with the green oil.

Separation of the paraffin.—The separation of the paraffin wax of various melting points has been referred to, but the methods employed are of such import that more detailed information is necessary.

The heavy oil is first cooled in tanks set in open sheds, and is then further cooled with freezing machines. The latter are generally ammonia solution machines, in which a solution of chloride of lime is cooled, and placed in a tank containing alternate compartments—wide ones for the oil and paraffin, and narrow ones for the brine solution. The oil and paraffin lie in these compartments for many hours, and solid paraffin crystallizes out. Beilby designed a cooler in which the paraffin lay undisturbed until sufficiently cooled, but such a method required much time for crystallization and necessitated a large plant. The Henderson form of cooler (Eng. Pat. 9557, 1884) is so arranged that a larger throughput may be effected. It is provided with a scraper, which removes the chilled mass of paraffin from the cold plate and permits the warmer material to move to the cold sides of the tank. Some works use dry ammonia gas, liquified by pressure, and utilize the cold by passing the paraffin mixture through pipes which are chilled by the evaporating ammonia gas. This produces more sudden chilling, and causes some paraffin to thicken in an amorphous state, difficult to separate from water.

From the cooling machines, the paraffin is broken up by machinery and then is pumped through filter presses. The paraffin is collected in the press, while the oil flows into its own tank. When the cooling is carried out by means of ammonia gas, without the interposition of the brine, many more filter presses are necessary because of the amorphous paraffin. The paraffin wax from the filter presses is further squeezed in cloths in hydraulic plate presses, and is called paraffin scale. The heavy oil separated from the solid wax is known as blue oil; the refining of this oil has been referred to above.

The crude paraffin was formerly refined by repeated crystallization from naphtha, but this is now accomplished by sweating. In the naphtha treatment the oily matters were removed by dissolving the paraffin in naphtha and allowing it to crystallize out. This operation was conducted generally three times, and the loss of naphtha amounted to about 200 gallons per ton of paraffin refined. The paraffin was freed from the adherent naphtha by being melted in a closed iron vessel, where it was exposed to a current of steam at 20 pounds pressure for 48 to 60 hours. The paraffin was finally decolorized by agitation for one and a half hours with animal charcoal, in pans, with a horizontal mixer.

In the sweating process, which is now generally used, naphtha is not employed, the paraffin being simply exposed to such a tempera-

ture that the softer paraffin is melted and runs away with the oil. In carrying out the process, the crude scale was formerly melted, and heated to about 180° F., in order that water and other impurities might be separated, after which it was run into pans of one to two gallons capacity and then allowed to solidify. The cakes were afterwards placed on cocoa fibre mats on inclined shelves and ovens, which were heated by steam pipes to abcut 30° F. below the melting point which the finished product was required to have. The portion which ran out was again treated in the same way and sweated at a lower temperature, and the drainings from it were cooled and pressed to obtain oil and scale, the latter being either worked up with the crude scale mixed with a portion of the intermediate wax, or worked alone.

In 1886, Tervet and Allison patented a cooling and sweating arrangement for treating large quantities of paraffin. It consisted of a cooling, and sweating chamber, each formed in three sections so that three qualities of wax might be treated. In 1887, Tervet patented another sweating apparatus, in which it was claimed that first-class wax could be obtained from crude scale in one operation.

In the sweating process patented by Norman M. Henderson (No. 1291, 1887; No. 11,799, 1891), which is now universally employed, a chamber about 52 feet x 13 feet x 10 feet, having steam pipes for heating it, and enlarged doors and ventilators which may be opened for cooling it, is fitted with a number of superimposed horizontal trays, about 21 feet x 5′–6″ deep, resting on transverse heating pipes. Each of these trays is supplied with a horizontal strainer of wire gauze of about sixteen meshes to the inch. The bottoms of the trays communicate with short pipes with nozzles constructed to work with worm wheels on a vertical shaft. Before charging the trays, the diaphragm, or strainer, is covered with about half an inch of water, which prevents the melted wax from running through the diaphragm. The crude solid paraffin from the filter presses, after being melted in the tank, is pumped through the vertical charging pipes, and through the small cocks on to the surface of the water, to fill the trays; and when it is solidified, the water is run off, the cake of paraffin resting on the gauze, and the doors and ventilators are then closed.

The stove is then heated for a considerable time to 80° F., and finally to the temperature at which the sweating is to take place, and the liquified impurities are drained off until the overflowing paraffin sets on a thermometer bulb at 130° F. The various liquids separated

in the refining of the wax are drawn off through the nozzles into hoppers on the standard pipes, which lead them into horizontal pipes through which they are passed to suitable receivers. When the sweating is completed, the remaining wax is melted by increasing the temperature and is run off through the same outlets into a tank, from which it is pumped for treatment with charcoal as in the older processes. The stoves used in this process are built of brick, and have double doors of iron and wood, generally with sawdust between. Each stove is fitted with two sets of nine pans each, and will take from two to three charges of 14 tons each per week according to circumstances. Larger capacity stoves are also in use.

At the Pumpherston refinery there are twenty sweating houses for refining the paraffin wax; each house contains two sets of nine pans each.

Mr. Norman M. Henderson has recently designed an improved apparatus for sweating paraffin wax, which he claims is superior to his older process. In this process the paraffin is sweated in cells; a sweating house for an installation of 144 cells being 50 feet long x 14 feet wide x 16 feet high. The full charge of paraffin wax in the cells is 32 tons, and the cells may be charged and run twice a week. Four such installations of 144 cells will give a throughput of 276 tons per week. At the Broxburn refinery, five installations are now in operation, and the authorities state that these stoves will replace the older ones as opportunity arises.

The cost of a refining plant is £11,000 per million gallons of crude oil run, and a refinery to deal with ten million gallons of oil per year would cost approximately £200,000, everything included. The cost of labour and everything in and for the refinery is three farthings to one penny per gallon of crude oil put through. Three classes of workmen are employed in the refineries: stillheadmen (three for each shift), who receive 5s. to 5s. 6d. per day; two assistants to the stillheadmen, receiving 4s. 6d. per day; and six firemen for each shift, receiving 4s. 2d. per day.

Products of Manufacture.

(1.) The permanent gases produced by retorting are used for fuel. The composition of these gases varies considerably, but the retort gas from Bryson retorts, using Pumpherston shale, generally contains 50 to 60 per cent of hydrogen and about 20 per cent of carbon dioxide.

(2.) Shale naphtha generally consists of 60 to 70 per cent of olefines and other hydrocarbons acted on by fuming nitric acid, the rest being principally of the paraffin series. It is completely volatile at ordinary temperatures, and is obtained at different specific gravities and boiling points according to requirements: for instance, 0·660 for gasoline, and 0·690 for motor spirit. Ordinary naphthas, the specific gravities of which range from 0·72 to 0·75, are used for lighting purposes, and as solvents and cleansing agents. The present price of naphtha is 7d. per gallon.

(3.) The burning or lamp oils are transparent and nearly colourless, having both the paraffin and olefine series in considerable proportion. They are used for lamps of many designs, and the specific gravities vary from 0·78 to 0·83. The following are the flash points of the principal Scottish burning oils:—

Young's Crystal..	128° F.	All of 18 c.p.
Pumpherston Pearline..	126° F.	
Broxburn Petroline..	126° F.	
Oakbank Kerosene..	126° F.	

Scottish oils have been free from lamp accidents since their manufacture. They are serviceable for continuous burning lamps, for buoys and lightships, and may be used for combustion in oil engines. The present price of burning oil is 6d. to 7¾d. per gallon.

(4.) Intermediate oils.—The specific gravity of these oils varies from 0·84 to 0·87, and the flash point is generally greater than 150° F. They are used for gas making, and at 800° to 900° C. a good Scottish intermediate oil will yield 1,200 candle power per gallon; it will be seen, therefore, that the gas produced is of high illuminating power, so they are largely used for enriching coal and water gas and also for combustion in oil engines. The present price of intermediate oils is £5 per ton.

(5.) Lubricating oils.—These oils are made with a specific gravity varying from 0·865 to 0·910, and are employed for lubricating purposes, either alone or mixed with vegetable or animal oils. It is worthy of note that shale lubricating oils do not decrease so rapidly in viscosity by heating as many other mineral lubricating oils. The present price of lubricating oil is from £5 10s. to £8 per ton.

(6.) Solid paraffin is used in vast quantities for candle making. Also for water-proofing, metal protection, insulating purposes, and a variety of well-known uses. The usual grades of paraffin are melt-

ing point 130°, 125° to 127°, 118° to 120°, and 110° to 112° F. The price of crude and refined paraffin varies from 2½d. to 3½d. per pound.

(7.) Still grease is the amorphous distillate from the end of the crude oil and heavy oil distillation. It is employed for grease making, and the present price is £4 to £4 10s. per ton.

(8.) Still coke.—This is the residue left in the still on distilling crude oil to dryness. This coke is worth from 40s. to 50s. per ton, and represents in the case of the best crude oil about three to four per cent of the oil, but in the case of the less pure oil, or where the distillation has not been properly conducted, it may amount to eight to ten per cent of the crude oil. It is used for gas fires in private houses, as a fuel in drawing-rooms, as a smokeless fuel for yachts, as carbon for electrical purposes, and for making moulders' blacking.

(9.) Sulphate of ammonia is used as a manure by agriculturists; it is especially useful for growing the sugar beet. Ammonium sulphate solutions have also found application in the preparation of fire extinguishers. The present price of ammonium sulphate is £11 15s. per ton (May, 1909).

(10.) Liquid fuel.—The acid and basic tars obtained in the refinery are used as a liquid fuel for the stills, together with the dregs and residues unfit for other purposes. It is probable that these tars would be valuable as wood preservatives, fluxes for mineral smelting, and for coating iron pipes to prevent the formation of rust. Owing to its high thermal value, there is considerable demand at present for liquid fuel, but in Scotland the tars are used solely for liquid fuel under the refinery stills. The ordinary products obtained by refining Scottish oil-shale are too valuable to be used for fuel. It is conceded that the use of liquid fuel is an ideal method of raising steam, but it has been found difficult to supply high-grade fuel oil at a reasonable cost; in fact, it is owing to this reason that the shale oil produced in Scotland, which has a calorific value of 18,217 B.T.U., has not been employed for fuel purposes, although some experiments were conducted at Woolwich Dockyard in England by the British Admiralty as early as 1866, with the view of testing the value of shale oil as a substitute for coal in raising steam in marine boilers. It should be noted in this connexion that one ton of fuel oil is equal in thermal efficiency to about one and three-quarter tons of steam coal, mainly owing to the diminished loss of heat up the stacks and the more equal distribution of heat in the combustion chambers.

The crude oil obtained by retorting the oil-shales of New Brunswick is especially suitable as a liquid fuel, owing to its thermal efficiency, and it may be produced in unlimited quantities at a minimum cost. The crude product obtained by retorting a large amount of shale from Irving's farm, Baltimore, New Brunswick, at the experimental plant of the Pumpherston Oil Company, Limited, possessed a specific gravity of 0·92, a flash-point of 194° F., a setting-point of 54° F., and a heating value of 18,474 B.T.U. It contained only 0·62 per cent of sulphur. It is interesting to note that this crude oil bears a resemblance to the crude petroleum of the mid-continent field; it yields 10 per cent of an asphaltic residuum on distillation, showing that it is of a semi-asphalt base.

(11.) Other products.—Scottish oil-shale does not yield vaseline, and no attempts have been made so far to manufacture tar products from the acid and basic tars.

Profits on a Ton of Shale.

At the present time, the average cost of mining and manufacturing products from one ton of shale in Scotland may be given as 8s. 3d.; and the net profit on the products of a ton of shale may be given as 3s. 4d. In 1882, the profit on a ton of shale amounted to 3s. 7d., while in 1897 the profit was 2s. (See Table of Dividends, etc.)

The regulation of wages, railway rates, and market prices of the various products, is controlled by an organization composed of representatives of the various Scottish oil-shale companies. In 1887, it was proposed to change into an oil syndicate or trust, but this was never effected. Only two strikes have occurred in the history of the industry: one in 1887, from July to October, and another in October, 1903. Perfect harmony now reigns, and there is a friendly understanding between the masters and workmen.

The development of the Scottish oil-shale industry has been carried out with skill and energy, and it is gratifying to note that the industry is now meeting with the commercial success it well deserves. It may be stated, however, that opportunities for improvements in the processes and wastes still present themselves.

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CANADA
DEPARTMENT OF MINES
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R. W. BROCK, DIRECTOR.

PART II

GEOLOGICAL POSITION AND CHARACTER

OF THE

OIL-SHALE DEPOSITS OF CANADA

BY

R. W. ELLS

OTTAWA
GOVERNMENT PRINTING BUREAU
1909

No. 1107

5656—5½

To R. W. BROCK,

Director Geological Survey,

Department of Mines.

SIR,—I beg to submit the following report on the oil-shales of Canada.

A geological and topographical map of the areas in Albert and Westmorland counties, N.B., is being prepared by Mr. Sidney C. Ells, B.A., B. Sc. This will serve to show the general structure of the district, and the distribution of all the known areas of the Albert shales (oil-shales) in these counties.

I have the honour to be, sir,

Your obedient servant,

R. W. ELLS.

JUNE 14, 1909.

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PART II

GEOLOGICAL POSITION AND CHARACTER OF THE OIL-SHALE DEPOSITS OF CANADA.

BY

R. W. Ells.

For more than half a century the presence of a well defined belt of shale and sandstone, of various colours, generally black, brown, and grey, in part highly bituminous, has been recognized in the south-eastern part of the Province of New Brunswick: especially in the counties of Westmorland and Albert, whence these rocks extend west into Kings county. From their occurrence and early development in Albert county they have been for many years known under the name of Albert shales. Rocks very similar in character, and regarded as belonging to the same geological horizon, have been long known in different parts of the adjoining Province of Nova Scotia, where they received the name of Horton series, given by Sir J. W. Dawson many years ago.

In New Brunswick, attention was first specially directed to these shales about 1849, as the result of an examination of the area by Dr. A. Gesner, a local geologist of marked ability, and the author of several valuable reports on the geology and resources of the Maritime provinces. In that year—1849, he discovered on Frederick brook, near what is known as Albert Mines, a remarkable deposit, consisting of a vein or bed of a bright jet-black shiny mineral, easy of ignition, and supposed by some persons to represent the outcrop of a bed of coal. On subsequent careful examination Dr. Gesner came to the conclusion that the mineral was not a coal in any sense, but a form of mineral pitch, or a hardened or inspissated petroleum, which occurred in vein form, cutting the enclosing strata transversely to the bedding, instead of occurring as a regularly bedded deposit after the usual manner of coal-beds. For this new mineral the name albertite was

suggested by Dr. James Robb to Sir Charles Lyell, at a time when the true nature of the mineral was still a matter of doubt.

The discovery of this mineral on Frederick brook in 1849 directed attention to the area at once, and in the same year the locality was visited by Dr. James Robb, professor of geology and natural history in the University of New Brunswick, at Fredericton. Under date of November 26 he writes: 'Dr. Gesner mentions the occurrence of a bed of coal at Frederick brook, a branch of Weldon creek, etc. I visited,' continues Dr. Robb, 'this place in October last (1849), and found on the land of Mr. J. Steeves, near the head of Frederick brook, a good deal of brownish bituminous substance, but no coal whatever. ....Mr. Steeves showed me what had been regarded as coal, but it proved to be a mineral pitch or hard bitumen; it had only been found, he said, in small rolled fragments in the surface drift of his field.

'The discovery of the existing Albert mine was due, I have been informed, to the bursting of a milldam on a branch of Frederick brook, which exposed the brilliant and massive veins of albertite, now the source of the mineral of the Albert mine.'

In 1852 a celebrated law-suit was commenced, involving the ownership of this peculiar mineral, which promised, when developed, to be of great economic value. Dr. Gesner, the original discoverer, claimed the mineral on the ground that it was not a true coal, and, therefore, was exempt from the ordinary Crown Land regulations applicable to that mineral, in which contention he was supported by Dr. James Robb of the University of New Brunswick, and by Mr. R. C. Taylor, of Philadelphia, a chemist of repute. Mr. W. Cairns, who was the appellant in the trial, contended that the mineral was a true coal, and as such was subject to the regulations then in force by the New Brunswick government. At the trial a large amount of evidence was taken by experts, with the result that the jury decided in favour of the contention that the mineral was a true coal. It may be added, however, that though Dr. Gesner by this decision lost his personal interest in the property, it has since been abundantly established that the contention advanced by himself and Dr. Robb was correct, namely, that it is true asphaltic mineral, occurring in veins, and not as a bed similar to bituminous coal.

As this mineral, known at first as Albert coal and now under the name albertite, proved on investigation to be of great value, and was mined for nearly thirty years, at a large profit, its subsequent history assumes an importance due to its direct association with the shale

deposits; though mining operations on this celebrated vein have been discontinued for 25 years. This deposit has often been described, and the property was surveyed and mapped by the Geological Survey in 1876-7, but complete records of the enterprise have never been obtained. Many of these records have been destroyed by fire, or otherwise; the principal persons interested have passed away; and no reliable data can now be secured. It may be said, however, that in each of the years 1865 and 1866 the output of albertite was 20,500 tons, while the total from 1863 to 1874 amounted to 154,800 tons, and during the entire period of working it was probably not far from 230,000 tons. The price ranged from $15 to $20 per ton, and mining was carried to a depth of nearly 1,300 feet. The length of the vein worked was, in a straight line from west to east, about 2,800 feet. It varied greatly in thickness, was frequently broken and thrown from side to side, sometimes thinning out almost entirely, and again increasing to a thickness of from 15 to nearly 17 feet. In its lower levels it passed into a brecciated mass of shale fragments, closely cemented with albertite, as was also the case at the extremities, which thinned out until it became unprofitable to continue mining. Several spur veins were found, with other smaller separate veins, but of these none were worked to any considerable extent. The vein did not follow the exact crest of the principal anticline in the shales, which was located in one of the tunnels from near the bottom of the west shaft, at a distance of 420 feet north. This anticline was also located at the surface in a couple of brooks, where it corresponded in position with that observed in the underground workings. The vein descended almost vertically 1,300 feet to the bottom of the workings, and was followed downward by pits and bore-holes to a further depth of about 200 feet, though the brecciated nature of the deposit at this depth rendered its working unprofitable.

Though numerous attempts have been made by borings, since 1876, to find other veins of this mineral in the shale areas, none of these have been successful outside the area of the Albert mines. It is probable, therefore, that conditions exist in that district, either through peculiarities of anticlinal structure, fissuring, or in the nature of the original deposit, which do not occur in other parts of the shale field.

The geological formations of the district may be briefly stated. At the base are pre-Cambrian rocks, consisting of schists and hard

slates, granite, and diorite. These form the ridge known as Caledonia mountain. In their extension westward from the Albert mines these rocks are almost continuous to the vicinity of St. John city. In Kings county they are overlaid by sediments of Cambrian age, well recognized by characteristic fossils, but in Albert county and eastern Kings these old sedimentaries are apparently absent, and the crystalline rocks are directly overlapped by a series of shales, conglomerates, and sandstones which are a part of the Devonian system, in which the portion known as Albert shales is included. For many years these were regarded as of lower Carboniferous age, but their abundant fauna of fossil fishes, together with the abundance of plant remains, some of which are similar to those found in the typical Devonian of Gaspé and elsewhere, together with the fact that everywhere yet studied they are unconformably beneath the recognized lower Carboniferous limestone series, in New Brunswick, Nova Scotia, and Newfoundland, have led to their being now regarded as an upper portion of the Devonian. The reason for this change in horizon is more apparent from the fact that westward in Kings county they have been found to constitute an integral part of the Perry group, which occurs at intervals from the western part of the Province through southern New Brunswick into Nova Scotia. From the most recent work on the rocks of this group, both in Maine and in New Brunswick, it has been conclusively established that this group really belongs to the upper part of the Devonian system, both by the fact that the shales and sandstone carry a well defined Devonian flora, and that everywhere it is unconformably overlaid by the series of marine limestones which are associated with deposits of gypsum in New Brunswick, and Nova Scotia, now regarded as constituting the proper base of the lower Carboniferous rocks, and of the Carboniferous system as a whole.

The views stated by Drs. Bailey and Ells, in the report for 1876-7, regarding the structure of the shale formation, though now modified in some respects by more recent study of the several districts, may be briefly stated.

The Albert shales form a belt extending from the Memramcook river, between Dorchester and Memramcook on the east to within a short distance of the village of Hampton, a distance of about 70 miles. The rocks of this belt are concealed at many places by overlying drift deposits or by lower Carboniferous sediments, comprising limestone, gypsum, conglomerate, marly shales and sandstone, which

overlie unconformably the shale formation. As these shales reappear at intervals on the general line of strike to the southwest, often with but little change in character, it is probable that the areas are continuous throughout, and are repeated at various points by the presence of anticlines which have brought the lower beds to the surface.

East of Albert mines no pre-Cambrian rocks are visible; but west of that place crystalline rocks of pre-Cambrian age rise abruptly in the prominent ridge known as Caledonia Mountain range, and, as already remarked, continue thence nearly to the city of St. John, the shale formation lying against its northern flank for some miles. Westward the strongly marked bituminous character of the shale decreases somewhat, but the formation as a whole can be readily recognized as far as the head of Kennebecasis bay, which is an arm of the lower part of the St. John river.

In Nova Scotia, rocks of similar age, also strongly charged with hydrocarbons, are developed at several points, though the well-defined brownish bituminous characters were not seen in this Province, the colour of the shales being generally black or greyish. These will be described later.

The formation evidently is continuous on Kennebecasis island, which lies in the bay of that name, a few miles north of St. John city, the shales here being grey and black, with grey and brown sandstones; but as far west as Apohaqui, along the south side of the Intercolonial railway, their character as brown bituminous shales is well preserved. They can be well seen on the roads between Sussex and Bloomfield to the south of the railway, and their bituminous nature is apparent in their westward extension nearly to Hampton, where some years ago they were mined in a search for coal. In this part of Kings county their position as a part of the Perry group can be well seen. This formation at the base consists of massive red conglomerate, shale, and sandstone, with a thickness of several thousand feet. These pass upward gradually into greyer and more sandy beds, alternating with grey and dark shales, which abound in plant remains, partly of Devonian aspect and partly of Carboniferous types. In places these upper shales contain fish remains similar to those of the Albert series, the associated plant remains, which are very abundant in certain layers, having a like similarity. The shales of Albert and Westmorland counties, according to the Geological Survey examination in 1876, show generally the following succession:—

Basal conglomerates—sometimes absent, but when present often greenish in colour, both coarse and fine textured, sometimes with reddish beds, and made up of the debris of the underlying pre-Cambrian rocks, the thickness not definitely ascertained, but variable—occur in isolated basins as in Kings county. They apparently pass up into calcareo-bituminous shales and sandstone, with thin limestone, grey to dark brown in colour, in places quite black, rich in hydrocarbons, with thin bands of ochreous weathering ironstone. Their thickness as measured in several sections is from 850 to over 1,000 feet. The shales are sometimes very thin bedded, or papyraceous, separating readily into thin flexible sheets, the surfaces of which are sometimes almost covered with remains of fishes. Other shales are greyish tinted, especially on weathered surfaces, but chocolate coloured on fresh surfaces, and are associated with hard and massive bands, well bedded, often destitute of apparent shaly structure or lamination, except on well-weathered surfaces of outcrops. These hard beds are very tough, break with a well defined conchoidal fracture, and are especially rich in hydrobarbons. They kindle readily and burn freely owing to the quantity of contained oil. In colour they range from almost a jet black to brownish-black, and sometimes are decidedly grey, with frequent streaks and layers of black bituminous matter somewhat resembling albertite. Portions of these beds show a very curly structure, indicating apparently a greater percentage of hydrocarbons in composition, as if they had been effected by movements in the mass, which were resisted by the denser portions of the shale beds. These massive bands constitute what are known as the oil-shales proper, though a large portion of the mass of brown bituminous shales, as well as of the grey beds is sufficiently saturated with hydrocarbons to ignite quite readily.

As has already been remarked, the fossil remains of fishes are quite abundant at places in the shale beds, some of the papery layers being almost covered with their impressions, while hard nodular masses, scattered through the shales, on splitting, often yield larger forms, also in a very perfect state of preservation. Large numbers of these fossils have been obtained from time to time, and, during the season of 1908, very full collections were made by Mr. L. M. Lambe, more especially in the vicinity of the Albert mines.

Numerous bore-holes have been put down by different companies to ascertain the presence or otherwise of crude oil, but, as in the case of the Scotch shale, all such attempts have resulted in failure

to find wells with an economic yield, the contained oils apparently being obtainable only by distillation. In many respects these New Brunswick shales correspond very closely with those of Scotland, which have for half a century been extensively mined and distilled with much success, but from which free oils of economic importance, either in the borings or the extensive underground workings, have never been obtained. As a very large portion of the Scotch shales has thus been proved, it is only natural to suppose that further attempts to obtain oils in the free state from such bituminous shales would be equally unsuccessful. It is possible that the lack of success attending the numerous boring operations in the shales of both countries, as regards finding native oil, may be due in part at least, to the generally disturbed and faulty nature of the ground.

In New Brunswick this feature is very pronounced, the strata being often highly inclined and the indications of faults numerous. The same features are seen in the several shale areas of Scotland; so that it would appear that no oil reservoir where large bodies of oil might accumulate actually exists in either country. That this is the case in New Brunswick, in Nova Scotia, and in Gaspé, seems to be fairly well established; for while small quantities of native oil have been found in a number of the wells—and there are several springs in the shale country which show its presence—up to the present time nothing of commercial importance has been met with, and boring operations have been discontinued for several years.

So far it has been impossible to obtain the logs of the wells from most of the localities where boring operations have been carried on. Of some 65 or 70 wells bored in the Memramcook-Petitcodiac district in New Brunswick, the logs of only three are available; at Baltimore also three have been obtained; while of those bored at Albert mines and at Elgin no record has apparently been kept. This is greatly to be regretted, since, had reliable logs been preserved of the strata passed through, our knowledge of the shale problem would have been largely increased. In none of these holes was the underlying base of the shale series apparently found, though at one point in the southern part of the Dover field a depth of 3,000 feet was reached. The only information obtainable is the verbal statement that red rock was at the bottom.

The record of several of these logs is appended, as showing in some degree the nature of the strata passed through.

LOGS OF BORE-HOLES AT BALTIMORE.

Boring No. 1, Diamond core-drill.

Elevation above sea-level, 710 feet, April, 1900.

H. B. Goodrich; Geologist in charge.

This hole was located on the flat of the east branch of Turtle creek, 1,800 feet northeast of the corner at Rosedale post-office. The boring evidently commences in the overlying lower Carboniferous sediments, and the log is as follows:—

	Feet.	
Gravel, surface drift		7
Green and red, coarse and fine conglomerate	60	67
Red marly shales, occasional pebbles	14	81
Conglomerate	4	85
Red clay shale	6	91

Unconformity, dips of above, N. 10-15 deg. representing the lower Carboniferous formation.

	Feet.	
Albert shale series—		
Fine sandstone, shale layers	7	98
Shale, calcite veins, holds oil and will burn	9	107
Shale with fine sandstone	4	111
Banded shale, calcite, pyritous, small quantity of oil	13	124
Oil-shale, contains much oil and burns readily	3	127
Oil-shale, burns, but not so readily	7	134
Bituminous sandstone and shale	10	144
Oily shale, but not a true oil-shale	1	145
Bituminous shale oil-bearing, burns more or less freely	27	172
Slightly bituminous claystone with shale bands	32	204
Shales and fine sandstone	10	214
Very fine sandstone (claystone), with shale layers	36	250
White sandstone	1	251
Black bituminous shale, with sandy layers, burns	19	270
Very fine-grained, probably calcareous sandstone	22	292
Black bituminous shale, burns freely	77	369
Black bituminous shale with sandstone beds	24	393
Fine dark sandstone with 3 feet shale	14	407
Light brown oil-stained sandstone	3	410
Fine sandstone, with shaly streaks, brecciated	20	430
Black bituminous shale, bands of fine sandstone	49	479
Very fine brown sandstone, in part rich in oil	27	506
Black shale rich in hydrocarbons	11	516
Sandstone, and shale, slightly bituminous	47	563
Fine grained sandstone	12	575
Fine black shale	27	602
Fine white sandstone	17	619
Clay shale, slightly bituminous	10	629
Fine white sandstone	2	631
Grey clay shale	8	639
Fine white sandstone	9	648
Black shale	46	694
Fine white sandstone	8	702
Black shale	7	709
White sandstone	5	714
Shale and sandstone	11	725
Fine sandstone to bottom	21	746

It will be seen that the lower part of this boring traversed a considerable thickness of white sandstone. This rock does not appear at the surface in any observed portion of the shale field of Albert county. The contact with the underlying crystalline rocks was, evidently, not reached.

Boring No. 2 at Baltimore. Diamond core-drill.

Elevation above sea-level, 891 feet. Begun, September 1, 1900.

H. B. Goodrich, Geologist in charge.

Location near summit of ridge west of Rosedale post-office near E. Steven's house.

	Feet.	
Gravel and clay		20
Grey clay-shale faulted, dips N. 15-20 deg	73	93
Quartzose mica sandstone, with thin shales	13	106
Micaceous fine grained sandstone with shales	26	132
Black clay shale	6	138
Oily sandstone	7	145
Whitish brown whetstone rock	5	150
Sandstone and shale	8	158
Oil-bearing sandstone with oil streaks	22	180
Grey shale and white sandstone	5	185
Black and green shale, no oil, dip N. 15 deg	38	223
Quartzose sandstone	7	230
Shale and sandstone	12	242
Grey and green shale	36	278
Fine micaceous sandstone	11	289
Shale and white sandstone	4	293
Grey and green shale, faulted, dip 20 deg	37	330
Sandstone and conglomerate	9	339
Shale	4	343
Whitish sandstone with some shale	8	351
White micaceous sandstone with oil at bottom	22	373
Green shale and sandstone, no oil seen	80	453
Mostly grey sandstone with shale partings	27	480
Grey shale broken and faulted	39	519
Claystone and micaceous sandstone	28	547
Dark grey shale	26	573
Claystone with shale bands	7	580
Grey clay shale	27	607
Sandy reddish shale	7	614
Hard fine grey sandstone	8	622
Grey shale	7	629
Grey sandstone	10	639
Dark grey shale	17	656
Hard dark grey sandstone and shale	62	718
Sandstone and fine conglomerate	12	730
Grey shale	12	742
Grey shale or slate to bottom of hole	35	777

From the above log it will be seen that the chocolate coloured shale so characteristic of the Albert shale formation elsewhere was not recognized, and that there are considerable thicknesses of sandstone, both grey and white. At the Albert mines the sections from the shafts and along the brooks show the brown beds more abundantly, with but small areas of the sandstones.

Bore-hole No. 3, at Baltimore, with churn drill.

Elevation above sea-level, about 800 feet. Begun December 4, 1900.

H. B. Goodrich, Geologist in charge.

	Feet.	
Soil..		1
Shale slightly bituminous, close grained and brown..	29	30
Hard claystone, or sandstone non-bituminous, brown bituminous shale, small showing of oil..	13	43
Shale slightly calcareous and bituminous; grey shale or claystone, calcareous and bituminous; shale with streaks of fine bituminous sandstone; hard grey calcareous shale slightly bituminous; grey shale slightly bituminous, calcareous bituminous shale with streaks of claystone, and sometimes with calcite veins, broken, with sandy layers..	70	113
Brown shale, probably oil-shale, bed of about 2 feet hard rock, probably rough claystone; calcareous shales, a bed of oil-shale 2 feet thick..	53	123
Grey shale, slightly bituminous; very bituminous shale, but probably not an oil-shale in places with calcareous bands; calcareous shale and claystone; grey calcareous, slightly bituminous shale..	47	170
Fine calcareous sandstone, with harder calcareous and bituminous shale and sandstone, passing into hard grey bituminous shale..	43	213
Hard, very bituminous shales, possibly oil-shale; calcareous shale and sandstone, faulted, bituminous claystone, calcareous shale and claystone slightly bituminous to bottom of hole..	35	248

Hole for entire distance in bituminous shales and claystone; a slight find of gas was given off, but no flow of oil at surface.

Principal concentration of hydrocarbons appears to be at 112 feet to 123 feet; secondarily important at 212 feet to 214 feet.

Location is approximately 10° southwest of a vertical line from face of big tunnel on the Baizley lot, and is at least 95 feet above level of that tunnel at collar.

LOGS OF BORE-HOLES AT MEMRAMCOOK AND PETITCODIAC RIVERS.

A number of bore-holes were put down, mostly with cable drill, in the area between the Memramcook and Petitcodiac rivers, and several were bored on the west side of the latter river, a short distance south of Stony creek. The greatest depth reached in these holes was a little more than 3,000 feet at Pré d'en haut. In all, nearly 80 holes were bored, the logs of which are available in some cases; but a close study of these does not furnish much information owing to the unsatisfactory manner in which these logs were kept. Holes Nos. 4, 5, and 7, were superintended by Mr. Goodrich—the geologist in charge of these boring operations—and the logs are as follows:—

Bore-hole No. 4, May, 1901.

Surface soil		6
Grey shale with black bituminous bands	50	56
Shale with hard bands	21	77
Black shale	43	120
Close grained sandstone or claystone	33	168
Dark bituminous shale	16	169
Hard rock, probably fine grained sandstone	7	176
Oil-bearing sandstone	28	204
Grey shale	41	245
Darker shale to bottom of hole	65	310

Bore-hole No. 5, August, 1901.

	Feet.	
Red clay and gravel		13
Hard grey shale	42	55
Hard grey shale and sandstone	5	60
Very hard shale with finer layers sandstone	40	100
Grey and black shale with hard limestone	26	126
Grey bituminous shale	4	130
Grey bituminous shales with sandy beds	10	140
Greyish and black bituminous shale	20	160
Greyish black bituminous shale with limestone	14	174
Sandstone with small show of gas and oil	4	178
Hard grey and black shale	42	220
Dark soft highly bituminous shale	20	240
Dark shale with sandstone	7	247
Oil sands	28	275
Shales to bottom of hole at	12	287

Bore-hole No. 7, September 24, 1901.

	Feet.	
Surface soil		20
Grey shale	92	112
Hard limestone	5	117
Grey and black bituminous shale	10	127
Hard rock, probably limestone	10	137
Grey and black, slightly bituminous, shale	70	207
Hard rock sandstone or limestone with shale	16	223
Black shale	5	228
Hard sandstone or fine claystone	8	236
Black shale	3	239
Hard brown sandstone, flow of gas	17	246
Black close grained shale, bituminous	27	275
Reddish shale	4	277
Black bituminous shale	46	323
Grey non-bituminous shale	47	370
Oil-bearing sandstone	37	407
Sandy shale to bottom of hole	4	411

The three holes indicated above were put down not far from St. Joseph's college, west side of Memramcook river.

DISTRIBUTION OF ALBERT SHALE SERIES.

The general distribution of the Albert shale series in Albert and Westmorland counties was shown on the map accompanying the Report of the Geological Survey for 1876-7. Some minor changes have been made at several points; but on the whole the delimitation of these rocks, as there shown, still holds good. No attempt was made on the map to indicate the several bands of oil-shale, owing to the smallness of the scale on which it was compiled. These were further

examined during September, 1908, and were measured at the outcrops in the several areas. Of these it may be said that workable beds are now known to exist in at least six localities, with further possibilities along the western extension of the Albert shales.

Beginning at Taylorville, on the Memramcook river, opposite Upper Dorchester station on the Intercolonial railway, four beds of very excellent character were uncovered. Of these, two beds were each 22 inches in thickness, one of 3 feet and one of 5 feet. These are largely of the curly variety. At the Memramcook outcrops near St. Joseph's college the oil-bands were not observed at the surface, but were apparently passed through in the borings. The former place is situated directly on tide water, and within a mile of the railway station, and is, therefore, very easy of access. From this place several thousand tons were shipped, in 1864, to the United States, apparently for use in gas works or for distillation at Boston.

No thick bands of oil-shales were uncovered either at Beliveau or at Dover on the Petitcodiac River side, but there is a strong probability that such exist in these areas, since the beds are evidently continuous across the district, the intervening distance being occupied by overlapping deposits of Millstone-grit age.

In Albert county, the area between the Petitcodiac river at Hillsborough and Albert Mines is also covered with Millstone-grit, and by the true lower Carboniferous formations, comprising marine limestone and gypsum, with conglomerates and shale, beneath which the Albert shale series emerges near the mines, at the Salisbury and Harvey railway. These underlying shales are thence well exposed, especially along the stream known as Frederick brook, where they were first discovered in 1849. Along this brook six well defined beds of oil-shale, in massive bands, were opened up. These are partly of the curly variety and partly of the plain, the thickness ranging at the surface from 3′–6″ to 7 feet, all of which may be classed as of very excellent quality, with a total exposed thickness of about 30 feet. While other beds have been passed through in sinking the several shafts by which the albertite vein was worked, the exact position of these cannot now be ascertained without boring, though pieces of this material can be seen in several dumps, and much of it belongs to the curly variety and should be exceptionally rich in hydrocarbons.

The deposits of albertite which occur in veins in this area have already been referred to, and while the use of this material as an enricher of bituminous coal in the manufacture of gas has largely

ceased, its high percentage of oils by distillation still makes it an important factor in the future development of these shales.

The shale deposits of this area terminate against the flanks of the Caledonia Mountain range, where they apparently become overlaid along its north side by the conglomerate and marly beds, with sandstone, to within a short distance of the village of Baltimore. At this place the shales again emerge from the unconformably overlapping cover, about half a mile east of Forsyth brook, which is a branch of Turtle creek, and on this brook the Albert shales are well exposed, resting against the flank of the crystalline rocks. On Baizley brook ¼ mile to the west, these shales contain several beds of very rich oil-shale, partly of the curly variety, the percentage of oils and ammonia being very high. They have been opened, to some extent, and it was from one of these beds that much of the material used in the old distillation works at this place, in 1862-4, was taken. Farther west, near the corner at Rosedale post-office, other beds are seen, and on the crest of the hill near the house of Edward Steeves others of very fine quality are exposed, and have also been opened by drifts to a point nearly 100 feet from the line of outcrop, with a north dip of 15° to 20°. Near this point is the bed now known as the Irving seam, from which the shale shipment sent to Scotland for the test on a commercial scale during the winter of 1908 was taken, the details of which have already been given.

These beds appear to strike west to the west branch of Turtle creek, in which direction they become greyer in colour. In all it is known that at least six well defined beds of rich oil-shale occur in the Baltimore area, and probably there are others not yet definitely located. The thickness of the seams at this place range from 4 to 7 feet, as given p. 140, Geol. Surv. Summary Report, 1908.

On the west branches of Turtle creek several other outcrops of oil-shale were observed. One of these, on the branch nearest Baltimore, has a thickness of about 15 feet, but other thinner bands are seen along the stream; while on a small branch of the west branch another seam of very rich shale of the grey variety has been partially opened up, and as nearly as could be measured had a thickness of 3′–6″.

In the Baltimore areas the Albert shale rests directly upon the north flank of the crystalline rocks, with a well defined north dip at moderate angles, and no underlying conglomerates are visible in this area. The measures, though somewhat faulted, are not so greatly

disturbed as in the areas to the east. The exposed breadth of these shales is not large, as they soon become covered to the north by the reddish beds and limestones of the lower Carboniferous formation, which in turn are capped by Millstone-grit.

Going farther west good outcrops of the shales are seen on Hayward brook, which is a branch of Prosser brook, and on the upper part of this stream three good beds with thicknesses of 4 to 5 feet, of a rich chocolate-brown oil-shale, are exposed near the contact with the pre-Cambrian rocks of the mountains. These beds are different in character from the oil-shale bands of Baltimore and Albert Mines, cutting readily with the knife, but are rich both in oils and ammonia. They also have a well defined northerly dip, but as the width of the outcrops is small and terminates a short distance west against a spur of the crystalline rocks, in the absence of development work, save at one point, little can be said as to the general structure.

The projecting spur of the pre-Cambrian rocks, which extends eastwards across Prosser brook for a mile or more, apparently terminates the shale belt just described, but on the north side of this spur, and near the road crossing of the Coverdale river in the east part of Pleasant vale, the brown bituminous shale again appears on the side of a ridge in a small anticline, overlaid directly by lower Carboniferous limestone and conglomerate. Thence westward they are exposed at intervals to beyond Mapleton, where they have a considerable development, and contain several beds of oil-shale to within a short distance of the crossing of Pollet river, north of Elgin corner; the shales in this portion keep to the south along the flank of the mountain range, and are associated with green conglomerates. The flat land along the river north of Elgin is occupied by drift deposits, probably resting on lower Carboniferous sediments, which in turn lie unconformably upon the shale series. West of Elgin the Albert shales are seen in a few places along Robertson brook, but here the rocks of this series are much less bituminous. Rich shale again appears on Montgomery brook, near the cross road from Goshen corner south, beyond which they are entirely concealed by overlying formations, and do not again appear at the surface until the branches of Trout creek south of Sussex in Kings county are reached. From this creek west the brown shales are again exposed regularly on a back road leading to Campbell settlement south of Norton, and are well seen at Ratters corner in this direction. They also outcrop on Moosehorn brook, and on a road south of Bloomfield, but their bituminous character is much

less pronounced, black, grey, and dark shales accompanying the brown beds. Farther west they appear in a railway cutting half a mile southwest of Apohaqui station, beyond which they are covered by drift deposits along the valley of Kennebecasis river, and show in a small outcrop to the north of this stream at a point two miles northeast of Hampton village, with some carbonaceous matter, which has been supposed to represent a coal deposit. This, however, has no apparent economic value, and the material taken from a shaft sunk at this place shows but slight trace of bituminous matter. Westward of this, on Kennebecasis island, while the shales of the formation are seen, as already remarked the bituminous character is absent.

THE OIL-SHALES OF NOVA SCOTIA.

The oil-shales of Nova Scotia have been known for half a century, and shortly after their discovery in Pictou county in 1859, were opened and mined to some extent under the name of stellarite, the output being used in the distillation of oil, and for admixture with bituminous coals in gas-making. The literature on the subject has recently been reviewed, and has been supplemented by recent examination in the field of the several areas.[1] The areas are quite numerous,

PICTOU COUNTY.

[1] The Pictou oil-shales belong to a different geological horizon to those of Antigonish; being referable rather to the Carboniferous rocks. Along the course of McLellan brook—which is a branch of the East river of Pictou, and lies to the southeast of New Glasgow—a number of outcrops of black shale are found, most of which are carbonaceous rather than bituminous. A number of samples were taken from different outcrops, and, as in the case of those from Antigonish county, were tested in the laboratory of the Mines Branch, Department of Mines. The locations from which these samples were taken are as follows:—

No. 1, McLellan brook, near Black's old mill site; No. 2, McLennan's mill, a short distance below the old fulling mill, described in report of Logan and Hartley, 1869; No. 3, Marsh brook, a branch of this stream from the east; No. 4, Marsh brook, outcrop about 150 feet above McKay's house; No. 5, Marsh brook, about 300 feet above McKay's house; No. 6, Shale brook, branch of McLellan at mouth; No. 7, Shale brook, upper end under grey sandstone cover; and No. 8, one mile west of Woodburn station, and 50 feet north of track.

Analyses of Pictou County Oil-Shales.

No.	Crude Oil.	Ammonium Sulphate	Specific Gravity.
	Imp. gals.	Lbs. per ton.	
No. 1.......	42·0	35	0·892
" 2.......	14·5	41	0·889
" 3.......	8·0	Not given.	0·903
" 4.......	3·0	" "	Not given.
" 5.......	9·0	" "	0·921
" 6.......	4·0	" "	Not given.
" 7.......	14·0	" "	0·902
" 8.......	14·3	" "	0·902

With the exception of the sample from No. 2, these results are not satisfactory—as regards yield of crude oil, and ammonium sulphate.

being found at a number of places in that part of Nova Scotia, east of the Avon river, and exposed at intervals, to the eastern part of Cape Breton. The shales apparently belong to several formations, in part belonging to the upper Devonian, and in part to the Coal Measures, and some are apparently associated with upper Carboniferous rocks, the latter two being in the county of Pictou.

The oil-shales differ in some respects from those seen in New Brunswick. There is a lack of the brown bituminous shales and thick hard oil-bands already described as occurring in New Brunswick, though in age many of those in the adjoining province appear to be on the same general horizon. In Nova Scotia the shales are more usually black in colour, containing also bands of blackish material which are rich in hydrocarbons, the black shale deposits being in places of great thickness.

Among these areas may be mentioned a basin of shales with thin coals, found a few miles north of Antigonish town, which has been opened to some extent, in the search for workable seams of coal. These coals have been regularly examined by the Department of Mines and found to be too impure to make a good fuel.[1] According to the Report of Mr. H. Fletcher, (G.S.C. 1886), no seams of workable coal appear yet to have been found in the peninsula north of Antigonish, the black shales there exposed being in some cases mistaken for coals, into which they pass at several points; but from many of these openings no trace of good coal has yet been obtained.

Mr. Campbell, in How's Mineralogy of Nova Scotia, 1868, has clearly shown that these oil-coals underlie the lower Carboniferous limestone at Big Marsh. He divides them into two groups, the lower 70 to 80 feet in thickness, including 20 feet of good oil-shale, 5 feet

[1] In view of the commercial possibilities of the oil-shale deposits which occur in large magnitude in eastern Nova Scotia, and which are referred to by Mr. Campbell in How's Mineralogy of Nova Scotia, samples from the principal deposits were collected in both Antigonish and Pictou counties since the above was written. Those gathered in the former county are principally from the Hallowell Grant—known usually as the Big Marsh, eight samples of which were taken as follows:—

BIG MARSH: ANTIGONISH COUNTY.

No. 1, is from Dan McDonald's property, on which a shaft was sunk forty years ago, to a depth of over 60 feet; No. 2 (curly shale), and No. 3 (plain shale), are from McLellan brook—a small stream about half a mile east of No. 1; No. 4 (curly), and No. 5 (plain), are from Sawmill brook, about one mile farther east; No. 6 from the bank on Sawmill brook; No. 7, from the branch of Sawmill brook: these are known as Dan Boyds; while No. 8 is from the Big Beaver—Hugh McInnis' property, several miles nearer the shore. It was supposed that these samples would fairly represent the nature of the several deposits in this district—most of which were worked to some extent in former years—and furnish a reli-

of which are curly cannel, rich in oil; the upper, 150 feet thick, in immediate contact with the limestone, and containing a large percentage of oil. Of the 5 ft. seam of curly cannel, he states that 'it will yield at least 40 gallons of crude per ton, and 15 feet of the remainder will yield at least 20 gallons.'

The black shales are associated with light grey micaceous shales, with impressions of broken plants, and are in places much faulted and sometimes steeply inclined.

In Cape Breton, around Lake Ainslie, where borings for coal have been carried on for many years, the beds of black shale are not visible to any large extent, much of the surface being drift-covered. Greenish and dark grey ripple-marked sandstone and shale are seen in which the borings have been carried on in former years, and in one of the holes put down near the shore of the lake, brackish water, with a strong taste of petroleum, oozes out. The rocks at this place are greenish-grey sandstone, and dark grey shale. The remarks of Mr. Fletcher, who has studied this district very carefully, show that in places, while these sandstones are seen, other beds of grey, green, rusty, red and purple argillaceous shale dip northwest at a high angle, with sometimes thin greyish, slightly bituminous, shaly limestone.

The grey sandy beds and shales may represent that portion of the Perry Devonian seen in New Brunswick on Kennebecasis island, which is apparently the non-bituminous extension westward of the bituminous shales of Albert county.

Dr. I. C. White, of Morgantown, West Virginia, made an examination of the Lake Ainslie district some years ago, and after a careful study of the whole area, and of the several borings made, expressed

able test of the shales, as to their yield in crude oil and sulphate of ammonia.

The following analyses were made in the laboratory of the Mines Branch, Department of Mines:—

Analyses of Antigonish County Oil-shales.

No.	Crude Oil.	Ammonium Sulphate.	Specific Gravity.
	Imp. gals.	Lbs. per ton.	
No. 1	4·0	8·7	Not given.
" 2	6·0	Not given.	" "
" 3	None.	None.	" "
" 4	10·0	38 0	0·893
" 5	23·0	34·0	0·906
" 6	11·0	22·6	0·917
" 7	10·0	17·0	0·890
" 8	7·5	Not given.	Not given.

the conviction that in this part of the island there is no geological evidence of the existence of petroleum in quantities large enough to make it commercially valuable. On the contrary, he says all the geological evidence goes to negative the supposition.

On the west side of McAdam lake, situated a short distance north of East bay, Bras d'Or lake, black and grey shales are exposed near the west shore. Some twenty years ago a shaft was sunk by American capitalists in a belt of the black shale, to a depth of 65 feet, which was subsequently carried down to a reported depth of 175 feet. A small retort was erected, but apparently was operated only a short time, the material on the dump showing black and dark-grey carbonaceous shales, with crushed and slickensided surfaces, portions of which were graphitized. No information could be obtained during a recent visit to the locality as to the results of the working. The place has long since been abandoned. Some portions of the black shales on a small brook which crosses the property were reported to burn readily, but the rocks generally are much crushed in the vicinity.

At Cheverie, near the mouth of the Avon river, in Hants county, where boring for oil has been carried on for some years, Mr. Fletcher reports that oil and bitumen have been found in cavities, joints, and fissures, in a mass of gypsum largely quarried in the neighbourhood, which overlies a great body of black carbonaceous shale, containing numerous remains of plants and animals, (Vol. XV, p. 393, G.S.C.), and thus 'supplying the materials for the supposed source from which petroleum was originated.' Along the shore thence east to Walton large bodies of these black shales are exposed, but so far as examined appear to be carbonaceous rather than bituminous. In the vicinity of Walton they are overlaid by red beds of Triassic age. They are much folded and faulted, showing anticlinal structures at various points. No oil has yet been found in any of the bore-holes, but the rocks resemble in many respects those at Antigonish. Similar black shales occur in the North river near Truro, in large volume, overlain by green and grey jointed sandstone; but no attempt to ascertain the presence or amount of hydrocarbons has yet been made.

These shales of Cheverie and other points closely resemble the rocks seen along the west side of the Avon river between Hantsport and Horton Bluff, where they have long been known under the name of the Horton series. They consist of heavy beds of black shales, with fish and plant remains, and have been regarded as the equivalent in position of the Albert shales of New Brunswick. They occur in

basin shape and show the presence of faults. In a boring made near the line between Hants and Kings counties, the rocks, penetrated to a depth of 1,500 feet, were light and dark-grey fine sandstone, underlaid by bluish-grey coherent argillaceous shale, with plant stems and bands of ironstone, to a depth of 800 feet, below which grey sandstone again comes in. Some of the shales are said to have the characteristic strong odour of petroleum.

Regarding the shales of this part of the Avon, Mr. Fletcher remarks (Vol. VII, p. 90a), 'the lower plant-bearing beds occur between the gold-bearing series and the lower Carboniferous limestone. They consist of whitish-grey and rusty, fine and coarse quartzose grits, coherent or loose in texture, interstratified with thick bands of blackish shining bituminous shale, like those of Hallowell Grant, Antigonish county, and East bay, Cape Breton, some of which will burn and have been used for coal, while others, full of rootlets, constitute true underclays.'

Among the most important of the oil-shales in Nova Scotia are those found in the Pictou coal basin. These have been known for fifty years, and shortly after their discovery in 1859 were mined for material for distillation. They are better known under the name of stellarite and may be described in some detail because of their possible use as a source of oil.

Oil-shales occur at several points in the Pictou basin, as at Stellarton, McLellan brook, on Marsh brook—a branch of the latter, Shale brook, on the shore of Deacon cove, and near the mouth of Smelt brook.

Of the stellar or oil-coal, first found in 1859 at Stellarton, Sir J. W. Dawson remarks in Acadian Geology, 1868, p. 339, that 'under the McGregor seam lies a very curious bed, known as stellar or oil-coal. It is 5 feet in thickness, having, according to Mr. Hoyt, the following section:—

Bituminous coal....................	1′–4″
Stellar oil-coal....................	1′–10″
Bituminous shale....................	1′–10″

'The material known as stellar coal is, as I have maintained in previous publications, of the nature of an earthy bitumen, and geologically is to be regarded as an underclay or fossil soil, extremely rich in bituminous matter, derived from decayed and comminuted vegetable substances. It is, in short, a fossil swamp muck or mud,

which, as I have elsewhere pointed out, is a character of the earthy bitumens and highly bituminous shales of the coal formation generally. Its value depends on the high percentage of illuminating gas and of mineral oil which it yields on distillation, and it is likely on this account to form an important portion of the products of this coal area. According to the results of different trials it is stated to yield from 50 to 126 gallons of crude oil per ton, the larger amount being apparently the yield of the pure stellar-coal, so named from the scintillatory appearance in burning. According to an analysis by Prof. How, of Windsor, this gives:—

	Per cent
Vol. matter	66·33
Fixed carbon	25·23
Ash	8·21
Moisture	0·23

'The sample to which the above analysis refers gave 126 gallons of crude oil per ton. The immense amount of petroleum obtained from wells in Canada and the United States has for the present diminished the demand for this earthy bitumen; but it is certain that it must again come largely into use as the wells diminish their yield, and additional uses are found for the mineral oils.'

In the Geological Survey Report for 1869, on the Pictou coal-field, by Sir W. E. Logan and Edward Hartley, the stellar-coal is described as occurring at several places, notably on Marsh brook, in a pit opened by Mr. Haliburton, thickness uncertain, stated as 4 feet. In this section a great thickness of black carbonaceous shale is found. Also in the section on McLellan brook a seam varying from 1″ to 8 feet, associated with black carbonaceous and argillaceous shale occurs. A seam on this brook, about 26 chains from the old fulling mill, was formerly worked by a Mr. Patrick, and supposed to be on the same horizon as that seen on Marsh brook. On the south outcrop on McLellan brook, at Patricks opening, Sir W. E. Logan remarks that from a statement of Mr. A. MacBean, 'in descending the slope the oil-shales maintained a thickness of from 2″ to 6″ for about 20 feet. They then gradually thickened to 5 feet in descending 60 feet farther, the dip gently inclining to the eastward. Descending 8 feet more the deposit diminished to nothing, and in 8 feet still farther the face of the fault presented itself, the strata being vertical. In the thickest part of the oil-shale a horizontal gallery was driven 20 yards to the left, and in this distance the seam

thinned from 5 feet to 15″, then again thickened and again thinned.

'From the description of Mr. MacBean, and from the specimens shown me, the best and most typical parts of the oil-shale appear to have a curly or felt-like structure. It is this part that varies so much in thickness, and while the bottom of the deposit remains even, the thinning arises from depressions on the upper portion, which are filled up with even layers of the more ordinary carbonaceous shale. The outcrops approach one another to the northwest, and the turn of the axis of the synclinal occurs about 300 yards from the margin of the brook. The measures associated with the oil-shale on the opposite outcrop as exposed in the brook are as follows, in descending order:—

Brown-grey, fine grained sandstone, weathers brown.
Grey compact sandstone, with very micaceous partings.
Dark-grey flaggy sandstone, weathers brown-grey.
Bluish-grey argillaceous shale.
Black highly carbonaceous shale.
Oil-shales from 1″ to 8 feet.
Black argillaceous shale.
Black carbonaceous shale.
Measures concealed for 164 feet.
Cannel coal, 3″.
Bituminous coal, 1′–6″
Greyish-drab, fine grained underclay with stigmaria.'

In the same report (1869), Mr. E. Hartley describes the outcrop of stellar coal as occurring on McCulloch brook, and on Coal brook. Of these he gives a section of the Albion and Acadia mines area, in which he places the stellar coal as follows:—

Good coal	1′–4″
Stellar oil-coal	1′–10″
Bituminous shale, oil band	1′–10″

'Two slopes have been sunk upon the oil-coal seam, namely the Frazer mine on Coal brook near No. 3 slope, and the Stellar mine on McCulloch brook. The principal value of this seam consists in the large quantity of oil contained in the bench mentioned as oil-coal in the general section, which in former years was extensively worked, the oil-coal or stellarite, as it has been named by Prof. Henry How, who first described it, selling for a high price for gas-making and distillation. The present low price of coal oil from the extensive

workings of petroleum in this country and the United States, combined with the high tariff on imported coal imposed by the United States, have combined to render the working of this seam unprofitable, and both workings are at present abandoned.' Mr. Hartley further adds: 'As the quality of this peculiar coal will receive special mention in the Appendix to this report, I will only add in conclusion that, from the large content of oil, this seam must at some time prove of considerable value. From pits sunk by the Acadia Coal Company, it would appear that the size and quality of the oil-coal bench improves towards the east, the greatest thickness (1′–10″) being procured from a pit sunk at the corner of Grove street and Pennsylvania avenue in Acadia village, which coal produced 120 gallons crude oil to the ton, the average yield from the Frazer mine being about from 60 to 65 gallons per ton.'

Of the coals found in the Marsh brook, (Haliburtons) and on McLellan brook (Patricks), Mr. Hartley states as regards the Patrick locality, 'the oil coal from this mine occurs both shaly and curly, the latter description appearing the most valuable. That portion having the curly texture much resembles the stellarite in appearance, but is much heavier and has a lighter brown colour. It weathers a very dark-grey. The following analysis has been made by Mr. Broome of some large samples, selected by Sir W. E. Logan in 1868.

	Per cent
Volatile below 200 C. water and some oil..	0·67
Volatile at 200 C. (oil).............	14·73
Total vol. matter..................	33·91
Fixed carbon..	6·11
Ash, (greyish-brown)...............	59·88
	99·90
Coke...........................	66·09
Sp. gr...	1·747

The oil-coal has been used in the manufacture of burning oil, I believe, but I am not aware of the quantity of oil produced per ton.'

Of the oil-coal or shale from the Marsh Brook specimen he says:—

'This substance appears to be an argillaceous shale of a greyish black colour, having a brownish streak; the bedding is not well

marked except on surfaces of fracture, where the lamination can be traced by numerous small brillant points, apparently bituminous, which are included between the laminæ. A thin section of this oil-shale under the microscope presents the appearance of a dark-brown or black ground, nearly opaque, with numerous spots of yellow which are translucent; the black ground being the shale, and the yellow spots the included hydrocarbonaceous matter. The following analyses of this substance have been made, the first of a specimen procured in 1868, by Sir W. E. Logan, from the pit on Marsh brook, known as Haliburtons pit.

	Per cent
Hygroscopic water	1·02
Vol. combustible matter	27·44
Fixed carbon	9·26
Ash (greyish-brown, shaly)	62·28
	100·00

Sp. gr. 1·68.

'Since the above analysis was made I have procured other specimens from the same pit, one of which was analysed by Mr. Broome with this result:—

	Per cent
Vol. at 100 C. (water and some oil)	0·596
Vol. at 200 C.	11·250
No. 1—Rapid coking.	
Total vol. matter	40·600
Fixed carbon	0·400
Ash	59·000
	100·000
No. 2—Slow coking.	
Total vol. matter	35·540
Fixed carbon	5·260
Ash	59·200
	100·000

'The above results show that the shale is composed almost entirely of volatile matter and ash, the amount of fixed carbon being dependent on the rapidity of carbonization. The shale has been tested for

oil, but the results I have not heard. Theoretically it should be a valuable oil-shale.'

Of the section given of the Stellar seam Mr. E. Hartley says:— 'These three divisions of the seam are quite separate and distinct in character. The substances from each were examined some time since by Prof. How, who first described the peculiar substance forming the middle bench, to which, from a likeness in some of its qualities to the so-called oil-coals torbanite and albertite, he has given the name stellarite from its throwing off sparks or stars of fire when lighted. From these three benches, Prof. How obtained, by analysis, the following results:—

—	Coal.	Stellarite.	Shale.
Vol. matter	33·58	66·56	30·65
Fixed carbon	62·09	25·23	10·88
Ash	4·33	8·21	58·47
	100·00	100·00	100·00
Moisture	....	0·230	
Sp. gr.	....	1·103	

'*Coal.* The coal appears to be merely an ordinary fat coking coal, with an unusually small percentage of ash for this region, but the bench being thin, the value of the seam depends principally on the two lower divisions, stellarite and oil-shale.

'*Stellarite.* This peculiar substance was first known and worked at these mines by the former owner, the late Mr. J. D. B. Frazer, of Pictou. It appears to be an earthy bitumen, or, to quote Dr. Dawson, a fossil swamp muck or mud, which he has elsewhere shown is the character of the earthy bitumens and highly bituminous shales of the coal-formation generally.

'*Bituminous shale or oil-shale.* This is a rather heavy brownish-black shale. The following remarks thereon include both this bench and the stellarite. The first series is taken from Mr. Hoyt's report to the Acadia Coal Company for 1866, and the analyses under the head of No. 1 refer to the stellarite, while No. 2 refers to the oil-shale.

Analysis by Professor Wallace, of Glasgow.

	No. 1.	No. 2.
Vol. matters	68·38	38·69
Fixed carbon	22·35	8·26
Ash	8·90	52·20
Sulphur	0·05	0·25
Moisture	0·32	0·60
	100·00	100·00
Sp. gr.	1·079	1·568
Weight per cubic foot	67½ lbs.	97 lbs.
Crude oil per ton	126 gals.	63 gals.
Gravity of oil	0·844	0·850
Coke per cent	31·25	60·46
Ash in coke of stellarite 28·48%		

Analyses by Prof. Penny, Andersonian University, Glasgow.

	No. 1.	No. 2.
Vol. matters	67·26	34·16
Fixed carbon	24·03	12·30
Ash	8·40	52·00
Sulphur	0·11	0·74
Water	0·20	0·80
	100·00	100·00
Sp. gr	1·069	1·612
Weight per cub. foot	66¾ lbs.	100 lbs.
Crude oil per ton	123 gals.	60¾ gals.
Gravity of oil	0·844	0·850

Quantity of Oil by Various Trials.

Trials by Mr. J. DeW. Spurr, of St. John, N.B., of No. 2 crude oil per ton	74 gals.
" J. Haworth, Boston, Mass., by steam process	65 "
" F. McDonald, Portland, Me., No. 2 crude oil	50 "

'By way of comparison, the following results from these and other oil-coals are introduced; the table is taken from How's Mineralogy of Nova Scotia, 1868:—

Union oil-coal of West Virginia affords		32	gallons of crude oil per ton.
Elk River oil-coal "	"	54	" "
Kanawha oil-coal "	"	88	" "
Leshmahagow cannel, Scotland,	"	40	" "
Albertite, New Brunswick,	"	92–100	" "
Torbanite, Scotland,	"	116–125	" "
Stellarite, Nova Scotia,	"	53	" "
" "	No. 2 (shale) from	50, 60¾, 63, 65, 74	"
" "	No. 1	123–126	"
" "	picked samples	199	"

'In the practical working of the Frazer mine, the result was about 60 gallons crude, and from 30 to 35 gallons of fine clarified oil per ton.

'It will be noted that the three oil-coals, or bitumens, known as torbanite, albertite, and stellarite in the list just given, appear to afford the best results in oil manufacture. It will, therefore, be of interest to compare full analyses of these three, forming a class by themselves, and again to compare this class with other mineral combustibles from which they differ to a greater or less extent.

'This subject has been thoroughly investigated by Prof. How, and the following tabulation of analyses and conclusions drawn therefrom are taken from his late work. Although most appropriately introduced here, many of the facts will be found useful for comparison with coals of other seams, and the remarks on the theoretical value of fuels is also of general interest.

'Having, on account of my former connexion with the British Admiralty coal inquiry, been one of those engaged to furnish chemical evidence in a famous trial at Edinburgh of the question whether the mineral known as Boghead coal, found at Torbanehill, Linlithgowshire, should be properly called a coal, I was naturally interested in the discovery of the stellar oil-coal, and got ultimate analyses made of it and of the Albert coal; also in the subject of a trial on the ground that it had been improperly called coal. These analyses were kindly made for me through Prof. Anderson, of Glasgow, who generously met my deficiency in the necessary apparatus, which I had not brought out with me. The results were most interesting, especially when compared with those obtained from bituminous and cannel coals. As to the former, I selected from those I had made in the Admiralty inquiry, analyses of English, Scotch and Welsh bituminous coals; and as to the latter, analyses of English and Scotch cannels made by other chemists. The following table shows the differences which obtain between these minerals in proximate and ultimate analyses and in specific gravity, and the ratio existing between the two most important constituent elements:—

ANALYSES OF BITUMINOUS, CANNEL, AND OIL-COALS.

Mineral.	Locality.	Proximate analyses. Sp. gr.	Vol. mat.	Fixed carb.	Ash.	Carbon.	Ultimate Analyses. H	N	S	O	Ratio of C to H	Authority.
Welsh bit. coal	Duffryn	1·326	15·70	81·04	3·26	88·26	4·66	1·4[illegible]	1·77	0·60	100 : 4·82	H. How.
	Newydd	1·310	25·20	71·56	3·24	84·72	5·76	1·56	1·21	3·52	100 : 6·79	"
	Ebbw Vale	1·275	22·50	76·00	1·50	98·79	5·15	2·16	1·02	0·39	100 : 5·73	"
Scotch bit. coal	Grangemouth	1·290	43·40	53·08	3·52	79·85	5·28	1·35	1·42	8·58	100 : 6·61	"
	Fordel	1·025	47·97	48·03	4·00	79·58	5·50	1·13	1·46	8·33	100 : 6·93	"
Eng. bit. coal	Broomhill	1·025	40·80	56·13	3·07	81·70	6·17	1·84	2·85	4·37	100 : 7·55	"
	Sydney	1·283	42·20	47·80	10·00	73·52	5·69	2·04	2·27	6·48	100 : 7·73	"
English cannel	Wigan	1·276	39·64	57·66	2·70	80·07	5·53	2·12	1·50	8·08	100 : 6·90	Vaux.
Scotch cannel	Leshmahagow	1·251	56·70	37·26	6·03	73·44	7·62	......	1·14	*	100 : 10·43	Miller.
	Capeldrae	......	......	.....	25·40	56·70	6·80	1·90	0·35	8·80	100 : 11·99	A. Fyfe.
Torbanite	Scotland	1·170	71·17	7·65	21·18	66·00	8·58	0·55	0·70	2·99	100 : 13·00	H. How.
Albertite	New Brunswick	1·091	54·39	45·44	0·17	87·25	9·62	1·75	......	†	100 : 11·02	Slessor and How.
Stellarite	Nova Scotia	1·103	66·53	25·23	8·21	80·96	10·15	0·68	......	‡	100 : 12·53	"

* Nitrogen and oxygen, 11·76. † Sulphur (if any) and oxygen, 1·21. ‡ N, S, and oxygen, 0·68.

'In the paper in question I pointed out that the true comparative value of combustible minerals, while partly indicated by the relative amounts of volatile matter and fixed carbon, is only truly shown when account is taken of the oxygen; which is sometimes large in quantity, as is seen above, and is reckoned as volatile matter, to the credit of the mineral, while its real effect is reduction of value. I showed that when the hydrogen—equal to the oxygen present—is deducted, taking only those cases where there is an apparent equality in the ratio of carbon to hydrogen, the last three minerals in the table above stand apart from the rest, thus:—

Ratio of carbon to hydrogen, after deducting hydrogen equal to oxygen present.

	Per cent
Cannel coal from Wigan..........	100 to 5·65
Cannel coal from Leshmahagow......	100 to 8·71*
Cannel coal from Capeldrae	100 to 10·05
Torbanite from Scotland..........	100 to 12·43
Albertite from New Brunswick......	100 to 10·85
Stellarite from Nova Scotia........	100 to 12·43

* Allowing 2% for nitrogen.

and that theoretically they should be excellent oil-coals as is abundantly shown by experience.

'*The Stellar seam.*—The size of the Stellar coal bench in the oil-coal seam varies from 4″ or 5″, to some 2 feet in thickness, and its content of oil varies also. As a rule this seam appears to improve going eastward, as stated by Mr. Hoyt. The general appearance of the Stellar coal is peculiar; it is irregularly bedded, the different layers seemingly interlaced, giving it a sort of entangled appearance, or a structure like felt. Sometimes the layers are much curved and have smooth surfaces like slickensides, which appear to have been produced by lateral movements, corresponding very nearly with the plane of the bed, rather than by vertical motion, the better layers generally possessing this peculiarity, whence the statement in many notices of this substance that the curly oil-coal is the best. The surfaces of these curved faces have a bright resinous lustre, and a brown-black colour, while a block sawn across shows a uniform deadbrown surface. It breaks with a splintery fracture, very irregularly, but approximately with the surface of deposition; the streak has a brown colour and a dull resinous lustre.

'A large splinter of this mineral may be easily lighted with a match and burns with a bright carbonaceous flame, throwing off sparks like stars (whence its name) and leaving but a small amount of coke, from which in burning off the fixed carbon a greyish-white ash is obtained.'

In the analysis of the Pictou coals, Mr. Hartley includes the results obtained from the stellarite at the Pictou gas works:—

'The yield of gas from the stellar coal of the Frazer mine was 11,000 cub. ft. per ton of 2,240 lbs., of illuminating power of 36 candles; coke worthless.

'From the oil-shale, 8,000 cub. ft. of 36 candle power.'

Of this he remarks that 'the stellarite and oil-shale of the Acadia mines are most valuable for mixing with the coals, to increase their illuminating power, but would not be of great value if used alone, for two reasons; because their cokes are worthless (being merely a cinder with only a small per cent of fixed carbon, and, therefore, useless for heating the retorts); and because the gases produced in carbonizing them are too carbonaceous for use with ordinary burners. Good coke is not only valuable to the gas-manufacturer as a merchantable product, but is also used for heating the retorts; and, therefore, cannels, and substances like torbanite, stellarite, and albertite, though producing a large amount of highly carburetted gas, are seldom used in gas-manufacture, except in mixture with coals furnishing a good coke.'

The following extracts taken from Prof. Henry How's Mineralogy of Nova Scotia, 1868, may be also quoted: 'Concerning the oil-coal of Antigonish county, Mr. J. Campbell reports a 5 ft. seam of curly cannel, which will yield at least 40 gallons of crude oil per ton, and 15 feet of oil-shale, which will yield at least 20 gallons per ton.' In the same volume he refers also to the shale deposits found in Hants county thus:—

'The non-productive coal-measures of Hants county afford large quantities of shale, which have led to expectations of finding coal, but the amount of oil they yield has not yet been ascertained. The deposits of shale in Antigonish county may be of the same age.

'These beds (in Hants) are very favourably spoken of by Mr. Campbell, from whose report I make a few extracts. The fact that the centre of the Antigonish basin is occupied by highly bituminous limestone, overlying the oil-coal and oil-shale beds, may possibly indi-

cate the whole group is upper Devonian or lower Carboniferous rocks, which are not known in this country to contain coal beds of any value.' On this point I may mention that in a depth of about 180 feet in the neighbourhood of Windsor only one small seam of coal, some 6″ thick, was found in 1864, and that in a shaft sunk at Hantsport in similar rocks, to a considerable depth, no coal was obtained.

Mr. Campbell goes on to say: 'The bituminous beds appear to be divided into two groups, the lower of which appears to be about 70 to 80 feet in thickness, 20 feet of which may be regarded as good oil-shale, including 5 feet of curly cannel rich in oil. The upper band, which lies in immediate contact with the limestone, cannot be much short of 150 feet in vertical thickness of strata, containing a large percentage of oil. Of this great bed of oil-batt about 30 feet will in all probability yield from 20 to 25 gallons to the ton. The 5 ft. seam of curly cannel will yield at least 40 gallons crude oil per ton, and the 15 feet of the best section of the oil-batt will yield at least 20 gallons to the ton, and taking this as worth 25 cents per gallon at the shipping port, there are in all $370,533,325 worth of oil which can be obtained from 20 feet in thickness of strata, underlying 2,000 acres of land comprising a basin underlaid by at least 50 feet in thickness of beds rich in oil.'

Up to the present, beyond the trials made in 1859-60 of the Stellarton oil-coals, but little attention has apparently been paid to any of these deposits. The principal work has been confined to putting down a few bore-holes in the search for native oils, none of which it may be remarked have been economically successful.

The quantity of oil-shale sold from the two mines at Pictou was about 4,000 tons, of the value of about $8.35 per ton at the place of shipment, and this was in part sent to oil-works in the United States. A portion of the stellarite was used in the Province to mix with ordinary gas coals as an enricher in the manufacture of illuminating gas. This shale was found in 1859.

By reference to Dr. H. S. Poole's map of the Pictou coal-field, published by the Geological Survey, 1904, the presence of this oil-coal is noted at a number of widely divergent points, so that it is evident that the material should occur in large quantity in this field. As already indicated, the raising of this mineral was stopped many years ago, on the discovery of the mineral oils in the United States shortly after 1860.

In view of the great prospective value of the stellarite or oil-coal of this district, the following data taken also from a paper by Dr. H. How, in Silliman's Journal, 1860, may be added:—

'The oil-coal found near Pictou, N.S., was first met with by persons residing in the neighbourhood, early in 1859, and its exact locality is called the Frazer mine. It occurs in the Coal Measures. I am indebted to Mr. Henry Poole, manager of this mine, for the following particulars relating to the geological position, etc., of the substance.

'The lowest measures—about sixty yards on the surface short of the distance where the oil-coal outcrops—are composed chiefly of strong bands of sandstone, actual thickness not yet proved; then shales with bands of ironstone, and stigmaria roots with sigillaria stems, and a few detached fern leaves in such soft shale that I have been unable to preserve any good specimens. Immediately above the oil-coal is a seam of bituminous coal about fourteen inches thick. Where we commenced to open a mine by driving a slope, the oil-coal was fourteen inches thick, but at 200 feet down, at the bottom of the slope, the oil-coal was twenty inches thick; it has a smooth regular parting at the top next the coal, as also at the bottom next the oil-batt below; but throughout its entire thickness it is of a curly, twisted, structure; many of its fractures look like the casts of shells, and the sharp edges are polished, of a slicken-sided character. No fossils that I am aware of have yet been found in the curly oil-coal. The oil batt next below is nearly two feet thick, of a homogeneous character, with a slaty cleavage of various thicknesses. In this band two or three varieties, (species?) of Lepidodendron, beautifully preserved, have been found, also leaves about one-fourth of an inch wide, and in lengths of from four to six inches, which have undergone so little change that when the damp shale was freshly split they could be removed, and were so elastic that they could be bent considerably without breaking. At the bottom of the slope another thin seam of curly oil-coal has appeared, of a few inches in thickness, but is not worked at present. In the roof coal were found pieces of decayed wood very little changed, which I consider a great curiosity. On McLellan brook the shale is above the oil-coal and oil-batt below, in which have been found lepidodendra, and apparently molar teeth with three fangs, flattened modiola shells, and spines or small fish teeth. The oil-batt has been found in several places without the curly band or so-called oil-coal. Two thousand tons of oil-coal have been raised

(Dec., 1859), at the Frazer mine.

'The oil-coal varies in colour from brown to black, is dull where not polished as just mentioned, has a reddish-brown lustreless streak, its powder is dark chocolate coloured, is very tough and breaks at last with a hackly fracture, its specific gravity in mass, after the vessel containing it had been in an exhausted receiver, is 1·103. It takes fire very rapidly, and when removed from the lamp still burns for some time with a brilliant smoky flame; and flaming melted fragments continually drop from it in a truly characteristic manner. Ignited as coarse powder in an open crucible it gives off abundant smoke and flame, then seems to boil quickly, and a coke is left of the bulk of the original material, showing when turned out a complete cast of the crucible. The ash of the coke is grey, and consists mainly of silicate of alumina; at least no lime, or a mere trace, is dissolved by acid, while some alumina is taken up, and a great deal of solid remains undissolved. The powdered oil-coal, digested with benzine and with ether, does not more than sensibly colour these fluids, but some residue remains on evaporation in each case.

'The bituminous coal occurring with the oil-coal had the usual characters belonging to the species; it was black, brilliant and very brittle. The approximate analyses of the two are placed side by side; and it will be obvious at once that they contrast very strikingly:—

	Oil-coal.	Bitum. coal.
Volatile matter.	66·56	33·58
Fixed carbon.	25·23	69·09
Ash.	8·21	4·33
	100·00	100·00

The following is the ultimate analysis of the oil-coal, for which I am indebted to Mr. Slessor, assistant to Professor Anderson of Glasgow, whose aid I requested from want of the necessary apparatus:—

	Per cent
Carbon.	80·96
Hydrogen.	10·15
[1]Nitrogen (by loss).	0·68
Ash as above.	8·21
	100·00

[1] With oxygen and sulphur.

The oil-batt appears to be decidedly a shale, and a specimen from Bear brook, Frazer mine, gave the following results:—

	Per cent
Volatile matters..........................	30·65
Fixed carbon.............................	10·98
Ash......................................	58·47
	100·00

Concerning the three substances, torbanite, albertite, and stellarite, Dr. How remarks 'that these three should prove, theoretically, the excellent oil-coals they are known to be. Of course the practical yield of oil will vary considerably according to the manipulation, the perfection of the manufacturing processes and the quality of the samples employed, but the following statement of the comparative amounts of oil afforded by some of the above may be taken as a good illustration.

'In Scotland the Leshmahagow cannel coal gives 40 gallons crude oil and 38 gals. rectified oil per ton.

'At McLellan brook, Pictou, the Frazer oil-coal gives 40 gals. crude per ton.

'At Coal brook the Frazer oil-coal and oil-batt together give 53 gals. per ton.

'At McCulloch brook the Frazer oil-coal gives 77 gals. per ton.

'The Albert coal or albertite gives 100 gals. per ton.

'The Torbanehill coal gives 125 gals. per ton.'

It will thus be seen that in Pictou county, where these shales outcrop at several points and are in large extent, the possibilities of successful development are such as to merit careful experimenting.

Going east to Antigonish county, in the paper by Dr. How, already quoted, he reports a 5 ft. seam of curly cannel which will yield at least 40 gallons of crude oil to the ton, and 15 feet of oil-shale which will give at least 20 gallons.

In the recent examination of these areas at Big Marsh, about nine miles north of Antigonish town, extensive outcrops of very black shales are seen, with others grey and reddish in colour. With these black shales are beds of coal, somewhat impure, containing a large percentage of ash. The black shales do not all kindle readily, but some portions burn freely, and should contain sufficient hydrocarbons to be of value for distillation. They are probably the shales referred

to by Mr. Campbell, already noted. They have not yet been tested, but are similar in character and belong apparently to the same horizon as those of Hants county, and are well worthy of careful examination as to contents in oil and sulphate of ammonia.

In Cape Breton also, somewhat similar shales, black in colour, with sufficient hydrocarbons to burn readily, are found at several points. They have been bored somewhat extensively for oil around the shores of Lake Ainslie, and at McAdam lake, the latter about 12 miles west of Sydney and already referred to. Though no economic results have yet been obtained at either place, the character of the shales is such as to warrant their examination as soon as facilities are afforded by this Department.

The details of the seams or beds in Albert and Westmorland have already been given.

OIL-SHALES FROM OTHER COUNTRIES.

The presence of oil-shales is recorded in several countries outside of Scotland, New Brunswick, and Nova Scotia.

Among the most important of these may be mentioned New South Wales, New Zealand, portions of the eastern United States, France, Saxony, etc.

The distillation of oil from shales preceded for some years the production of native oils obtained by boring, and a reference to this as applying to the United States is given in Sir Boverton Redwood's volume on Petroleum and its Products, Vol. I., 1st Ed., p. 14, in which he says:—

'Shortly after the introduction of Young's process for obtaining paraffin and paraffin oils by the distillation of coal and shale, a considerable number of refineries were erected in the United States, and were worked under licences from the Young's Company. At some of these imported coal was distilled, but most of them received their supplies of raw material from the extensive shale and coal deposits of Virginia, Kentucky, and Missouri. Near Boston, Mass., the large works of Downer were erected at a cost of half a million dollars, and at Portland, Me., Mr. Downer erected smaller works for distilling imported coal.

'The manufacture of oil from coal and shale continued to increase until there were not less than fifty or sixty establishments devoted to this industry in the United States, one of which was in Portland, one in New Bedford, four in Boston, one in Hart-

ford, five in the environs of New York, eight to ten in Western Pennsylvania, twenty-five in Ohio, eight in Virginia, six in Kentucky, and one in St. Louis. Many, if not most of these were of small capacity, however, and the greater part of them were not more than fairly started when the discovery of petroleum prostrated the whole business and threatened its projectors with overwhelming loss, from which they were happily rescued by converting their oil factories into refineries, which was done with very little trouble. (Henry).'

HISTORY OF THE SCOTCH OIL-SHALE INDUSTRY.

The manufacture of oil from coal and shale commenced in Scotland, or was attempted there more than a century ago, but the enterprise was not at first attended with success. Shale distillation was commenced in France at a yet earlier date, and the industry is still in operation. In Scotland the father of the industry was apparently Mr. James Young, who, in 1847, began the distillation or refining of crude petroleum, which occurred in a coal pit at Alfreton, and continued until the petroleum was exhausted; but its occurrence with coal led Mr. Young to continue his experiments on the distillation of coal itself, experimenting with various kinds of Scotch and English coals, until the famous Torbanehill mineral, or Boghead coal, was discovered in West Lothian. This proved suitable for distillation, and the works at Bathgate were started in 1850 by Messrs. Young, Meldrum, and Binney.

The supply of this mineral became exhausted in 1862, and attention was then directed to the great supplies of bituminous shale which occur in the areas west of Edinburgh. The yield of oil from the Torbanehill mineral was about 120 gallons per ton, while that from the shale when first used was only 40 to 45 gallons. The industry of distilling crude oils from shales thus commenced has continued to the present, with varying conditions of success, until now the enterprise is one of the most profitable in the British islands. In view of the great competition arising from the immense supplies of native oils found in Russia and the United States, the early methods of distillation, and subsequent manufacture, have become completely revolutionized, and so greatly improved that at the present time the Scotch shale works are still able to compete successfully with the production from outside sources. This has, however, been due largely to strict

attention to the values of the several by-products, such as sulphate of ammonia, paraffins, etc.

Bituminous shales suitable for distillation are found at a number of places, notably portions of Australia, in New Zealand, France, etc. In France, at Autun and Buxières, they have been worked since 1858. This shale is said to resemble the Boghead coals, and one analysis by Redwood gives about 50 gallons crude oil, yielding by fractionation:—

Burning oil and spirit, 25 gals.
Lubricating oil, 10 gals.
Paraffin, 2½ gals.

Large deposits of shale are also found in Servia, the yield of oil from which is stated to be from 43½ to 45½ gallons per ton, and by fractionation per 100 gallons crude:—

Burning oil, sp. gr., 0·810–0·820.	30 gals.
Intermediate oil, sp. gr., 0·840–0·865. . . .	4½ "
Lubricating oils, sp. gr., 0·880–0·885. . . .	15½ "
Paraffin scale hard and soft.	14·3 "

Of the nature of this deposit Redwood states that the principal shale seams appear to consist of leaf shale 6 metres or 37′–6″, and sandy shale 26 metres or 163 feet, with bands of poorer shale above and below.

Extensive deposits of shale are also reported from the Ronda district in the south of Spain.

In Saxony the mineral principally employed in distillation is apparently a brown coal or earthy lignite. The works here are very extensive, and have been in operation for more than half a century. In 1880 the amount of lignite mined for this purpose was over 9,000,000 tons.

In England the principal deposits from which oil is extracted by distillation are the Kimmeridge shales, which have a very extensive development in Dorsetshire. Tests of these made in Scotland some years ago gave about 50 gals. crude oil, and 38 lbs. sulphate of ammonia per ton. This percentage is, however, as in all shales, subject to frequent variation.

Apparently some of the largest and most important of the oil-shale deposits occur in New South Wales. In the recent report by Mr. J. E. Carne, 1903, on the kerosene shales, full details of the industry are given. The material is known under different names, as kerosene

shale, torbanite or boghead coals, cannel and parrot coals, wollongongite, etc.

At the date of the report on New South Wales (1903), the mineral was worked at four localities. The geological horizon appears to be in the Permo-Carboniferous or upper Coal Measures of that country. The seams of oil-shale appear to follow the usual habit of changing in thickness from point to point, and the material varies in colour from black to brownish-black. Though apparently massive it is mostly laminated as seen on weathered surfaces, in which respect it resembles the heavy bands of oil-shale of eastern New Brunswick. In physical characters portions of these deposits resemble closely the New Brunswick shale except that they appear to yield a much less amount of ash. Analyses of certain bands by Mr. C. Humfrey, of St. Davids works near Chester, England, of what is called the Hartley coals, give as much as 150 gallons crude per ton. In the pamphlet accompanying the New South Wales exhibit in the Franco-British exhibition, London, 1908, the shale being from the Wolgan and Capertee valleys, the yield of gas from this shale was stated to be 17·560 cub. ft. per ton, with an illuminating power of 48·52 standard candles. The yield of crude oil is stated as 101 gals., of sp. gr. 0·877 the results by fractionation being:—

	Per cent
Naphtha (motor spirit)	8·48
Illuminating oil	19·50
Gas oil	15·87
Lubricating oil	22·80
Scale	6·42
Residue	3·28
Vitriol, tar, etc.	24·65
	101·00

As in Scotland, the experience that shales rich in oil are low in sulphate of ammonia is confirmed, and in the workings the lower grades in oil are used for the manufacture of sulphate. One analysis of the Murrucundi kerosene shale, by Dr. A. Helms, gave 19·04 pounds avoirdupois of ammonia, equal to 69·8 lbs. sulphate of ammonia.

The great quantities of bituminous and oil-shales found in New Brunswick, and also in certain parts of Nova Scotia, and the repeated failures to obtain native oils from these deposits by boring in

both Provinces, led to a test being made of one of the bands of rich oil-shale in one of the large Scotch works. A shipment of between 40 and 50 tons was sent over to Scotland, and this was tested in the retorts of the Pumpherston Oil Company, located near Uphall in MidCalder, as already described. This test, carried out under the supervision of the Department of Mines, was very thorough, the fractionation being completed in the laboratory of these works. For the purpose of comparison with other shales, it may be stated that the total yield from 36¾ long tons of shale was 1,473 gals. crude, an average of 40·09 imperial gals. per ton, sp. gr. 0·919, or in wine gals. (U.S) 48 gals. with sulphate of ammonia 77 lbs. per ton. It is interesting to note that from other analyses of these shales from New Brunswick the theory that shales richer in oil are correspondingly poor in sulphate of ammonia is not sustained, since in the case of another sample giving 54 gals. imperial, or 65 gals. wine measure, the percentage of sulphate of ammonia was 110 lbs. and in another case, with 51 gals. imperial, the sulphate was 111 lbs. Of yet another sample, with oil contents of 30 imp. gals., the sulphate amounted to only 75 lbs., so that the ratio between the oils and the sulphate is not constant.

In the recent investigation of the Scotch oil-shale industry, made by the Department of Mines, the work was greatly facilitated by the excellent bulletin published by the Geological Survey of Scotland (1906). From this the following notes are taken, supplemented by personal observations of several of the largest mines in the oil-shale district, partly from an examination of several of the typical sections there presented, in which the oil-bearing rocks are exposed, and in part from the excellent report on the industry already referred to, under the direction of Dr. J. Horne, the able Director of the Scottish division of the British Geological Survey, which is at present under the control of Dr. J. J. H. Teall.

In this report (1906) the geology of the shale district has been very carefully worked out by two of the colleagues of Dr. Horne, viz., Mr. H. M. Cadell and Mr. J. S. Grant-Wilson; the methods of shale working have been written by Mr. W. Caldwell, mining manager of the Pumpherston Oil Company; and the chemistry of the oil-shales by Mr. D. R. Steuart, chief chemist of the Broxburn Oil Company. To all these gentlemen I beg to express, in connexion with my work of investigating the oil-shale industry of Scotland, my hearty thanks, for much courteous consideration and for great assistance in examin-

ing the rock formations, also for much information relative to the various processes of oil manufacture and distillation, and for statistics connected with the industry as a whole, an industry of great economic importance to Scotland at the present time. To Mr. Norman Henderson, manager of the Broxburn Oil Company, and to Mr. G. Bryson, manager of the Pumpherston works, at which latter place the distillation of the New Brunswick shale shipment was carried out, I am also indebted for much information, and for permission to photograph the principal portions of the several plants, etc.

The Geology of the Scotch Oil-shales.

In the study of this problem comparisons were made, as carefully as possible, with the known formation as developed in New Brunswick.

The Scotch oil-shales are a peculiar group of rocks which occur in a somewhat broad and well-defined belt, lying largely to the west of Edinburgh, but are developed on both sides of the Firth of Forth. They are described in the Memoirs of the Geological Survey of Scotland under the name of the Calciferous Sandstone series. In position they lie between the recognized lower Carboniferous formation, including the marine limestone, and the upper Old Red Sandstone of the Devonian system. Their apparent position will be better understood by reference to the following scale of formations, taken from the report in question:—

The succession downward in this part of Scotland is as follows:—

(1) *Carboniferous formations, proper.*

Coal Measures; carrying several important coal-seams, worked for many years in the area between Glasgow and Edinburgh, and mined extensively at a number of points. They comprise red sandstones, shales and marls, with no workable coals, underlaid by white and grey sandstones and shales, with numerous valuable coal-seams and ironstones. They underlie a series of red sandstones, the exact horizon of which has not yet been determined, but in general character they resemble in eastern Canada the rocks known as upper or Permo-Carboniferous.

(2) *The Millstone-grit*; consisting of sandstone and grit, generally grey, with layers of greyish conglomerate, the latter holding pebbles of white quartz, resembling in this feature the basal portion of the Millstone-grit formation as developed in New Brunswick and parts of Nova Scotia. Beds of brown or chocolate coloured shale and sand-

stone also occur as a part of this formation, as well as thin beds of coal. This formation passes upward into the productive measures, and has a thickness in Scotland of about 700 feet.

In descending sequence they pass down into the upper part of Division 3:—

(3) *Lower Carboniferous limestone series,* which embraces three divisions. Of these the upper division contains three or more limestones, with thick beds of sandstone and some coals; the middle includes several valuable seams of coal and ironstone; and the lowest carries several beds of marine limestone, with sandstones, shales, some coals, and ironstone.

In the fact that workable coals occur in this division of the lower Carboniferous they differ from this formation as developed in eastern Canada, in which, up to the present, no workable coal has been found. There also appears to be an absence of the thick reddish and green conglomerates, so conspicuous in New Brunswick, and an almost entire absence of the great deposits of gypsum so conspicuous in New Brunswick, Nova Scotia, and Newfoundland, at the base of the lower Carboniferous formation. Below the formation as thus described, is found in Scotland the Calciferous Sandstone formation, while in New Brunswick occurs the Albert shale series, unconformably underlying, and in Nova Scotia its equivalent the Horton series, also unconformably beneath the gypsum and marine limestone. The sequence in Scotland, however, is stated to be quite conformable between the beds of No. 3 and the Calciferous Sandstone series.

(4) *The Calciferous Sandstone series* in Scotland occurs in two divisions. As already intimated, the upper is apparently conformable beneath the lower Carboniferous division, and is known as the oil-shale group, with a thickness of over 3,000 feet. In the upper part it carries beds of coal, usually of inferior quality, and lower down a number of seams of oil-shale, six or more in number, which are interstratified with sandstones, shale, fireclay, marls, and estuarine limestone. The lower division, in which no shales are yet known to occur, at least of economic value, consists of whitish sandstones and shale, which pass down into grey, green and red shales, clays, marls and sandstone, with bands of argillaceous limestone or cement stone.

In this respect there is also a similarity as compared with the rocks of New Brunswick and Nova Scotia, since thin seams of impure coals occur in the equivalents of the Albert shale group in Nova Scotia both at Debert and in Antigonish, while in the several bore-

holes at Baltimore, N.B., several beds of white sandstone of considerable thickness have been located, with the usual association of shales similar in character to those observed in Scotland. In the latter country, however, the development of the red and white sandstone near the base of the series is much greater than yet observed in New Brunswick.

On the whole, therefore, omitting minor points of detail, the general development and succession of these rocks is very similar to that observed in the Provinces of New Brunswick and Nova Scotia. The chief point of difference in structure is that already noted as to the unconformity existing between the Albert or Horton series, which are the equivalents of the Calciferous sandstone series; and the overlying marine limestone or lower Carboniferous formations. In this respect also the Canadian shales fall naturally into the upper Devonian series, known in New Brunswick as the Perry group, which consists, at the base, of a great thickness, aggregating several thousands of feet, of reddish conglomerate, sandstone and shale, passing upward conformably into greyer beds of shale and sandstone grit, the latter often coarse, the grey beds throughout containing an abundance of plant remains, both of Devonian and Carboniferous types, with the remains of fishes. This group was for some time regarded in eastern Canada as of lower Carboniferous age, but recent investigations, especially on the plant remains, as developed in the western part of the area, have shown that it should be regarded as a portion of the Devonian system. This also confirms the statement made years ago that, owing to the lack of conformity everywhere, it should be separated from the lower Carboniferous as developed in the Maritime Provinces. The geological position of the Albert or oil-shales, both in Scotland and in eastern Canada, therefore, with this feature excepted, appears to agree fairly well. The presence of great numbers of fossil fishes in the Albert shale series, apparently very similar to those obtained from the bituminous shales of Scotland, has also a marked bearing on this question.

The determination of the plant forms obtained from the Perry group was made some years ago, after a special investigation by Dr. David White of the United States Geological Survey, who obtained a rich flora in the Perry rocks as developed in eastern Maine. The group first received its name from the town of Perry, where these rocks were studied nearly fifty years ago by Sir William Dawson, who at that early date unhesitatingly pronounced them as of upper

Devonian age. Their extension thence eastward through southern New Brunswick into Albert county, with the occurrence of similar rocks in Nova Scotia, was determined some years ago, and from the plant remains collected at various points numbers of the species known as *psilophyton,* and others of a like horizon, were obtained similar to forms found in Gaspé peninsula in Sir William Logan's typical Devonian section of that area.

The characters of the Albert shales, their structure as a whole, and the associated rocks, were very fully described in the Report of the Geological Survey of Canada, 1876-7, by the writer, and Dr. L. W. Bailey. Their characters as developed in Nova Scotia have been stated by Mr. Hugh Fletcher in several publications.

The Oil-shales of Scotland.

The oil-bearing shale of Scotland is a fine-grained brownish (or sometimes brownish-black and black) clay shale, which can be readily distinguished in the field. The brownish oil-bands are interstratified with non-bituminous or less bituminous beds, sometimes of a bluish-grey colour, known to the miners as blaes; and when destitute of bituminous matter and occurring as barren blaes, or ribs of hard calcareous or quartzose matter, as kingle.

The blaes variety decomposes much more readily on exposure to the weather than the oil-shales; and the bluish-grey colour (whence the name blaes), when the shale is decomposed into clay, is readily recognized. The oil-shales, probably from the presence of the bituminous matter in composition, strongly resist the action of the atmosphere and remain for years on the dump, the brown shale of the surface changing to a bluish-grey tint, without much loss of hydrocarbons. The beds or bands are persistent for long distances, but sometimes lose their bituminous character, and pass into the bluish or blaes variety. In this respect they also resemble the material of the Albert shale series.

The oil shales of the district are known as plain and curly, like those of New Brunswick, the plain being flat-surfaced, often with a slickensided aspect, due doubtless to sliding, through the agency of faults, while the curly variety is somewhat contorted or curled. They are both quite soft and free from grit, yielding readily to a sharp knife, and can be shaved off in thin shavings without breaking during the process of cutting. In the greater part of the rich oil-bands of the Albert shale series portions are curly and other parts of the same

band are plain, but the rock itself is much harder than the Scotch variety, and while it can be cut with a knife it does not shave readily. Certain bands, however, show features much like those of the brown oil-shales of Scotland, especially those from Hayward brook, which yield a large amount of oil and sulphate of ammonia. The curly variety is usually richer in hydrocarbons, which have possibly rendered it more easily crumpled than other poorer portions of the same bed (since both varieties occur in close association) associated with it. The blaes variety weathers readily, is more gritty in texture and on weathering passes into muds. All these varieties are seen on the large dumps at the Albert mines in New Brunswick. On the whole, therefore, it may be said that the oil-shales proper are somewhat different in the two countries, since in New Brunswick these are more massive, tougher, breaking with a well defined conchoidal fracture, show but small signs of shaly structure or lamination, except on well weathered surfaces, and show the presence of well defined black oily streaks. Though often apparently massive in general aspect they are, therefore, properly styled a close compact shale. Here also the curly variety is richer in hydrocarbons than the plain variety, the results of several analyses showing oil contents which range from 30 gallons to 54 gallons imperial, with a percentage of sulphate of ammonia from 67 lbs. to 111 lbs. per ton. They thus contain a much higher percentage of hydrocarbons than the Scotch shales at present worked, resembling more closely in character some of the cannel coals, or the poorer grades of torbanite of Scotland, or the stellarite of Nova Scotia. This variety of oil-shale in New Brunswick has received locally the name cannelite. When burned in the grate it burns readily with a long yellow flame, gives out great heat, small splinters kindling readily from the flaming of a match, is exceedingly tough, and when struck with a hammer gives out a dull woody sound. The associated shales are generally brownish, frequently polished on smooth surfaces, and often resemble the richer beds of Scotch shale. Other portions are black, sometimes greyish in colour, while portions of the shale mass are in thin papery layers, which contain sufficient hydrocarbon to burn readily. This form of shale has recently been tested to ascertain its contributory value in the production of mineral oil and ammonium sulphate; and in many cases was found to be very rich in both the necessary hydrocarbons and ammonia gas.

These shales, as is also the case in Scotland, are often traversed, sometimes along the bedding, by bands of hard yellow or ochreous coloured ironstone resembling a hard fine-grained dolomite. They resemble the cement stone bands found in the Scotch shales.

The value of the Scotch shale, as now mined, does not entirely depend upon the yield of oil by distillation, and as a rule those now worked do not seem to be as rich in this material as in the earlier days of the industry. Much of the present value depends upon the percentage of ammonia; the by-product sulphate of ammonia, obtained from the mingling of the ammonia derived from the retorting of the shale with a certain amount of sulphuric acid, forming a very valuable material with regard to the profit arising from the industry. The amount of paraffin is also an important factor. The amount of crude oil now obtained by retorting the Scotch shale rarely exceeds 30 gallons per ton, and shales as low in oils as 10 to 15 gallons are now retorted, owing to the fact that the yield of ammonia is held to be larger in shales poor in oil than from those of high grade in this respect. The yield of sulphate of ammonia is, therefore, a most important factor in estimating the profits arising from the distillation of shales, owing to the extensive demand for this substance, in agriculture. In operating shale deposits the matter of the by-products must always be carefully considered.

Regarding the thickness of oil-shales proper worked in the Scotch field, this varies greatly in different parts, or even in different portions of the same mining area. The oil-bands sometimes increase very materially, and vary from a few feet or even inches in thickness, to 6, 8, 10, and in some cases 15 feet, interstratified with blaes or bluish-grey portions less rich in bituminous matter, or with hard calcareous or siliceous bands.

It is practically impossible to obtain, in any portion of the Scotch fields, continuous sections of the shale beds at the surface, owing to a wide-spread mantle of drift, and the consequent paucity of good sectional exposures. In consequence the geological structures of the several districts have been largely obtained by a close study of the underground workings, and from the numerous bore-holes. Certain bands of rock thus struck are easily recognized, and serve as fixed points to determine positions. The thin papery shales seen in New Brunswick, with their abundant fish fauna, are rarely met with, but small veins of fibrous gypsum, or sulphate of lime, are found in places along the joint planes of the shale beds; and these with the yellow

weathering bands of cementstone or ironstone are a prominent feature at many of the mine openings, and in a few exposed local sections. All these are features common to the New Brunswick shales.

According to a paper recently published by Mr. D. R. Steuart, chief chemist Broxburn Oil Company, in *Economic Geology,* Nov.-Dec., 1908, and reprinted in the *Canadian Mining Journal,* Dec. 15, 1908, there are in the Calciferous Sandstone series of Scotland some twenty seams that have been or are capable of being worked. Of these not more than six or eight, exclusive of the Pumpherston seams, are now utilized. It has been found that those lying at a high stratigraphical level are the richest in oil, yielding in some cases as much as 45 gallons per ton, while from the lowest worked, as small a yield as 10 to 16 gallons is obtained. As regards the yield of sulphate of ammonia he states that the reverse obtains, the upper beds, rich in oil, yielding 20 lbs. or so, while the lower, poor in oil, give as high as 70 lbs. per ton.

'The strata of the oil-shale field being wrinkled into numerous waves as described, the result of the folding and faulting is to bring again and again the same seams to within working distance of the surface over a considerable area. In searching for shale in a new locality many bores have to be put down, and trial pits, to make certain the shale is sufficiently extensive to be worth the expense of a mine or pit shaft, otherwise faults may render the whole undertaking fruitless.'

Of the shale beds principally worked in connexion with the oil-shale industry of Scotland, which pertain to the Calciferous Sandstone series, and catalogued by Mr. D. R. Steuart, it may be said that those mostly occur between two well defined horizon markers, viz., the Hurlett limestone and coal at the summit of the series, and the Burdiehouse limestone near the base. The only workable seam of importance above the Hurlett was apparently the celebrated Torbanehill mineral, which occurred near the base of the productive coal-measures and above the Millstone-grit, while below the Burdiehouse limestone a series of five seams, known as the Pumpherston group, are found at a distance of about 800 feet beneath the limestone itself.

The details of these several seams of oil-shale are given in the report of the Mines Branch, and it will suffice in this place to state that they vary considerably both in their content of crude oil and sulphate of ammonia, as also in their thickness. Of these oil-shale

seams there are about eight which are now, or have been, worked at some time between the two boundaries indicated, in addition to the five of the Pumpherston group, or some thirteen in all. They vary in thickness from nearly 2 feet, as in the Addiewell seam, to about 8 feet in the Barrack seam and the Jubilee of the Pumpherston; while in the contents of oil and sulphate of ammonia they range from 16 to 20 gallons crude and from 55 to nearly 70 pounds of ammonium sulphate per ton in the Pumpherston group, to 40 and 55 gallons crude and 14 pounds sulphate of ammonia in the Raeburn seam at the top of the section. The conclusion can be easily reached that the Scotch shales are in no way superior to those examined from New Brunswick, but are in fact much inferior in the percentage of both these important substauces.

All these seams in Scotland are known by practical workings to vary considerably in thickness at different points. Several of them have been worked in former years more extensively than at present. The presence of the two horizon markers—the Hurlett limestone near the top of the shale series, and the Burdiehouse limestone near the bottom—are important factors in the examination of the shale fields, as from these fixed points the determination of the several seams can be usually readily recognized in the several areas when cut in the bore-holes. As in New Brunswick and Nova Scotia, the strata are thrown into a series of folds, which bring certain portions of the oil-bands to or near the surface over a large area. They are also affected by numerous faults and consequent displacements of the beds. A feature not yet recognized in eastern Canada in connexion with the shale formation is the presence of intrusive rocks, comprising volcanic necks and sills, largely a dolerite, with beds of ashy tuffs. The intrusives have affected the oil-shales along the contact, often depriving them of their bituminous or oily contents, and sometimes the igneous rock contains drusy cavities, which hold pitch or solid paraffin, that have apparently been distilled from the contained hydrocarbons by the action of the heated intrusive upon the bituminous shales passed through. The shales in contact often present a burned aspect, deprived of the hydrocarbons and rendered useless for retorting. In this respect they contrast very strongly with the bituminous shales of eastern Canada; but on the Gaspé shore, in the Devonian section between Gaspé bay and Point St. Peter, there is a beautiful illustration of a dolerite dike which cuts the Devonian sediments, and contains numerous drusy cavities which are filled with

petroleum, evidently derived in the same manner from the shales as seen in Scotland. Some of these igneous masses render the mining of the Scotch oil-shales difficult, as they have to be cut through in the workings at great expense. In places the mining is now carried on at depths of over 1,000 feet from the surface.

As a preliminary to all mining operations the careful testing of any desired area is most desirable, and in the Scotch areas is carefully attended to, in order to obtain all possible data relative to the thickness and extent of the several seams of oil-shale. This work is done by core drill, generally with diamond bits, and the cores carefully taken, thus giving reliable information as to the nature and location of the several beds passed through. All this work is done with great care, and so carefully have the records been kept, and so well are the characters and positions of the several beds passed through known, that in many cases any particular seam met with can be easily recognized. In New Brunswick, where much boring has been done for a number of years, no such careful work has been attempted, and either through carelessness on the part of the drillers, through badly kept records, or carelessness in keeping the samples taken, or possibly through ignorance on the part of the men in charge as to the exact nature of the rock traversed, much valuable information has been lost, and much of this boring will require to be repeated before the actual value of the several fields can be ascertained.

Shale mining is carried on very much in the same manner as the mining of bituminous coals. The roof has to be supported with the usual timber props, provision made for pillars, and a regular system of roads, driveways and drifts installed. In Scotland, powder in small charges is generally used as an explosive, owing to the soft nature of the oil-shale. The roof usually separates readily from the associated oil-bands.

In the regular process of mining the broken down shales are brought direct to the surface by wire haulage, and transferred thence to the breaker, into which the loads are discharged prior to the commencement of the retorting.

Seams of Shale now Worked in the Scotch Oil-shale areas.

Of all the shale seams mentioned in the Memoir of the Geological Survey, 1906, there were worked in 1903, according to the Report of H. M. Inspector of Mines, the following:—

The Broxburn grey seam (9) at Broxburn and Oakbank.

The Broxburn curly (10) at Broxburn, Dalmeny, Philpstoun, Forkneuk, and Oakbank.

The Broxburn seam (11) at Broxburn, Addiewell, Polbeth, and Hopetoun.

The Wild shale (12) at Oakbank.

The Dunnet (14) at Pumpherston, Newliston, Ingleston, Limefield, Duddingston, Cousland, Deans, and Starlaw.

The Oakbank new shale (15) at Oakbank.

The Barracks seam (16) at Cousland, and Deans.

The Pumpherston seams Jubilee (17), Curly (19), Plain (20), and Undershale (21) at Roman Camp.

As in the case of several of the New Brunswick borings, native petroleum has been found in several places in small quantity. Of these, between the Dunnet shale and the Oakbank new seam, from 100 to 200 barrels of crude oil were obtained, and in a boring of about 100 fathoms sunk in 1884 to the north of the Albyn works, the rods came up coated with crude petroleum of semi-solid consistency. In a cutting made in 1886, in the Sandhole pit and about 950 yards from the bore-hole, and in a level driven through inclined strata, there was a constant oozing of petroleum and brine, together with a strong smell of gas. In the pit and the bore, the petroleum was found below any seam worked, about 10 fathoms below the Dunnet shale. It is also remarked that petroleum probably exists in a layer over an area of considerable extent in that district. In other parts of the Broxburn field the shale brought up from bores from near the Dunnet position has a strong smell of petroleum.

It will be seen from the above that in none of the extensive workings which have been carried on for so many years in the Scotch fields has native oil of commercial importance yet been encountered. In this respect these shales closely resemble those found in New Brunswick and Nova Scotia, in which Provinces borings have been carried on extensively in a search for native oils, for more than 40 years. At several localities the presence of oil springs has been long known, and this fact undoubtedly influenced the location of the borings both here and in Gaspé, where these springs are quite numerous. In most cases, however, such springs evidently occur near lines of faults. It may be here remarked that in none of these borings in eastern Canada has oil in economic quantity been encountered, and apparently no underlying reservoir of petroleum exists, though finds of small quan-

tity have been struck in a number of bore-holes. In the extensive works at the Albertite mines only slight traces of native oil were ever met with. In Scotland small traces of albertite have been found, but no veins of workable size. Besides the albertite, the minerals ozokerite, asphaltum, elaterite and anthracite have also been obtained in the Scottish field, and the presence of a mineral wax has been observed in cavities in the igneous rocks at several places. In Gaspé, Quebec, the igneous dike at Tar point on the coast contains numerous small cavities filled with a black tarry petroleum, evidently the result of distillation from the Devonian shales, which are there penetrated by the igneous intrusion.

Torbanehill Mineral.

While interest in the Torbanehill mineral, or torbanite, of Scotland has long since ceased, owing to the exhaustion of the deposit, its close resemblance to the stellarite of Nova Scotia is such that the following further remarks on the nature of the former mineral may be offered.

Torbanehill mineral was evidently the most important of the oil-bearing minerals obtained from the Scotch fields. Its characters are given by Mr. D. R. Steuart thus:—

'The Torbanehill mineral was of a brown or nearly black colour; there were brown and black varieties, and the brown was the richer. It had a yellow or fawn-coloured streak, without lustre, and sub-conchoidal fracture, was amorphous, and apparently homogeneous when fresh, but showed distinct stratification when spent in the retort. It was very indestructible and did not deteriorate with weathering. Near basalt dikes it became soft, sticky and brown, resembling melted indiarubber. In the laboratory, it took fire readily when put to a flame, split, did not fuse, burned with a very smoky flame, gave an empyreumatic odour, and left considerable amount of white ash.

The crude oil taken from it was 96 to 130 gallons per ton, sp. gr. about 0·890. It was richer in the east part of the field than the west, and it deteriorated somewhat with depth. It yielded 44 to 48 per cent of crude oil, and 1 to 1½ per cent of solid paraffin. Heated in a close crucible it gave (Dr. Fyfe) 60 to 70 per cent of volatile hydrocarbons; 6·6 to 13·3 per cent fixed carbon, and 12·8 to 23·2 per cent of ash. The sp. gr. varied from 1·17 to 1·316.

The following analysis is by Anderson:—

	Per cent
Carbon	64·02
Hydrogen	8·90
Nitrogen	0·55
Sulphur	0·50
Oxygen	5·66
Ash	20·32
	99·95

The ash by analysis gave:—

	Per cent
Silica	56·09
Alumina	40·04
Peroxide of iron	3·24
Lime	0·34
Magnesia	0·46
	100·17

The seam varied from 1″ to 30″ in thickness, and there were vertical joints that cut it into irregular cubes. In a pit at Torbane the section was as follows:—

Boghead house coal	2′–7″
Arenaceous shale	6′–7″
Shaly sandstone	0′–7″
Shale and ironstone, remains of plants and shells	0′–10″
Cement stone,, impure limestone	0′–4″
Boghead channel	1′–9″
Fireclay full of stigmaria	0′–3″

Comparison of Stellarite with Torbanite.

For comparison with the Scotch mineral the description of the stellarite or oil-coal from Pictou, as given by Dr. Henry How, may be given. He says: 'The oil-coal varies in colour from brown to black, is dull where not polished, has a reddish-brown lustreless streak, its powder is dark-chocolate coloured, it is very tough and breaks at last with a hackly fracture, its specific gravity in mass, after the vessel of water containing it had been in an exhausted receiver, is

1·103. It takes fire very readily, and when removed from the lamp still burns for some time with a brillant smoky flame, and flaming melted fragments continually drop from it in a truly characteristic manner. Ignited in coarse powder in an open crucible it gives off abundant smoke and flame, then seems to boil quickly, and a coke is left of the bulk of the original material, showing, when turned out, a complete cast of the interior of the crucible. The ash of the coke is grey, and consists mainly of silicate of alumina; at least no lime, or a mere trace, is dissolved by acid, while some alumina is taken up and a great deal of solid remains undissolved. The powdered oil-coal digested with benzine and with ether does not more than sensibly colour these fluids, but some residue remains on evaporation in each case.'

The following analysis by Mr. Slessor, assistant to Prof. Anderson, is given:—

	Per cent
Volatile matters	66·56
Fixed carbon	25·23
Ash	8·21
	100·00

The ultimate analysis by Mr. Slessor is as follows:—

	Per cent
Carbon	80·96
Hydrogen	10·15
*Nitrogen, by loss	0·68
Ash as above	8·21
	100·00

* With oxygen and sulphur.

A comparison of the Torbanehill mineral and the Albert coal or albertite is given by Dr. How:—

Torbanehill mineral—

Vol. matter	71·17	Carbon	66·00
Fixed carbon	7·65	Hydrogen	8·58
Ash	21·18	Nitrogen	0·65
		Sulphur	0·70
		Oxygen	2·99
		Ash	21·18
	100·00		100·00

Albert coal or albertite—

Vol. matter	54·39	Carbon	87·25
Fixed carbon	45·44	Hydrogen	9·62
Ash	0·17	Nitrogen	1·75
		Ash	0·17
		Oxygen and sulphur	1·21
	100·00		100·00

The proximate analyses of the three minerals may also be added:—

	Sp. gr.	Vol. matter.	Fixed carb.	Ash.
Torbanehill, Scotland	1·170	71·17	7·65	21·1
Albertite, N. B.	1·091	54·39	45·44	0·1
Stellarite, N.S.	1·1039	66·53	25·23	8·2

The analysis of the Joadja mineral of New South Wales, Australia, taken from Mr. Carne's report on the kerosene oil-shales, 1903, is as follows:—

	Sp. gr.	Vol. mat.	Fixed carb.	Ash.	
Joadja oil-shale	1·108	89·57	5·27	4·98	T. Steel.

New Zealand.—Three samples from various localities, described as a variety of tobanite. Analyses as follows:—

	Fixed carb.	Hydro. carb.	Water.	Ash.
Mongonui	11·17	33·18	14·61	41·04
Cambrian	26·02	56·05	12·83	5·10
Waimate	9·81	27·99	16·19	46·01

An analysis of Kentucky cannel coal, Old Kentucky Boghead, by George R. Hislop, Paisley, Scotland, given for comparison, is as follows:—

Vol. matter, containing 0·44 of sulphur		55·36
Coke, consisting of carbon,	35·17	
sulphur,	0·18	43·43
ash,	8·08	
Water, expelled at 212° F.		1·21
Sp. gr., 1·175.		100·00

Characters: The coal is black, possesses a high lustre and yellowish-brown streak; fracture slaty, coarse and dull, with impressions of stigmaria, while in cross fracture it is conchoidal, with coating of fireclay in the natural partings; very compact and cohesive. On the fire it partially and slightly intumesces; colour of ash, brown; well defined in stratification and of very uniform density. Of this Gesner says that, 'by the ordinary methods of working, this coal yields 130 gallons crude oil per ton, of which 58 per cent was manufactured into lamp oil, and 12 gallons into paraffin-oil and paraffin.'

Oil-shales of Newfoundland.

For many years the presence of black highly bituminous shales has been known in Newfoundland, and these have been referred to in several of the reports of the Geological Survey of that island. Recently a small sample of this black shale was sent to the Department of Mines, Ottawa, which was, however, too small to be used for analyses for crude oil or ammonia, but which showed the presence of hydrocarbons, igniting readily with the flame of a match, giving a bright yellow flame and a strong odour of petroleum. On inquiry of the Director of the Geological Survey of that Province, Mr. J. P. Howley, he states that shales of a more or less bituminous nature are known to occur at several places, but that no attempt has yet been made to exploit them, except by boring operations at several points on the west coast.

Samples sent from the north side of Notre Dame bay from outcrops at Cap Rouge peninsula were analysed some years ago by a Mr. Chance, of Philadelphia, the result being: vol. hydrocarbons, 36%; fixed carbons, 35%; ash 29%; the material being called a cannel shale. He also adds that about Deer lake loose pieces can be picked up, very black in colour, of which splinters ignite rapidly, and that large deposits of similar shale occur along a small tributary flowing into the Humber above Deer lake, and that there is much shale of the same character along the north side of Grand lake.

Oil-shales of Quebec.

In the Province of Quebec, the occurrence of shales of the character just described is rarely seen. The Carboniferous rocks are not exposed west of Chaleur bay in Gaspé peninsula, but there is a large development of Devonian sediments in that area, the whole thickness of which aggregates over 7,000 feet. While oil-springs are found in the vicinity of Gaspé basin, at the eastern extremity of the peninsula, all attempts at finding petroleum in economic quantity by borings have as yet been unsuccessful.

At several places beds of bituminous or oil-shales are seen, varying from a foot to 15 inches in thickness, but in so far as examined these beds are quite local, though found at intervals for some miles on their strike along the north side of York river. Of these beds, which are associated with greyish sandstones, Sir William Logan remarks in Geology of Canada, 1863:—

'Some beds of these rocks contain a peculiar resinous matter, which forms the cementing material. It appears on the fractured edges of the beds as in the form of irregular laminæ, rarely an eighth of an inch in thickness, and generally much less. It has a vitreous lustre, a conchoidal fracture, and is tough, with a hardness nearly equal to calc-spar. Its colour is deep reddish-brown, but it gives a fawn-coloured powder, and when in thin plates or fragments, is translucent, and has an orange-red colour. This substance has neither taste nor odour, is insoluble in alcohol, naphtha, or potash-ley, and is but slightly attacked by nitric acid. It is scarcely fusible; but at a high temperature is decomposed, with a slight softening and swelling, giving off abundance of inflammable vapours, and leaving a small quantity of brilliant spongy coke. It has the characters of a fossil resin, somewhat like amber, but approaches more nearly to what has been named scleretinite and middletonite.

'The portions of sandstone impregnated with this resin burn, when kindled, with a brilliant flame, and much smoke; and the residue, which consists chiefly of siliceous sand, has very little coherence. Partial analysis was made of four fragments of this rock, which were supposed together to represent an average of the mass. The amount of volatile matter, of fixed carbon or coke, and of incombustible residue was as follows:—

	I	II	III	IV
Volatile matter	32·4	22·8	42·8	30·4
Carbon	8 9	8 1	7·4	8·9
Residue	58·7	69·1	49·8	60·7

'The purest specimen is seen to yield the smallest amount of fixed carbon. The excess of this in the others is due in part to the small portions of mineral charcoal generally present among the layers of this resinous sandstone. This material could be made to furnish large quantities of illuminating and lubricating oils, by a process of distillation similar to that applied to coal and to bituminous shales. In some experiments made on a small scale to test its power of producing illuminating gas, it was found that a few pounds of this material, which lost, by distillation, 26 per cent of its weight, yielded two and a quarter feet of gas of superior illuminating power, to the pound. As this quantity of volatile matter corresponds to about 33 per cent of resin, it is evident that if obtained in a state of greater purity this material would become valuable as a substitute for coal in gas-making.

'The specimens which served for the preceding experiments were obtained from a bed of from fourteen to fifteen inches thick, which was found near Shaw's mill, on the north side of Gaspé basin, and was traced for a distance of about 200 feet before it became concealed by the overlying sandstones. In numerous localities along the York river, for a distance of nearly thirty miles, small interrupted beds of a similar nature are met with in the sandstones. Those observed had a thickness of from four to twelve inches, and are sometimes a hundred feet in length. Some of them are composed in great part of laminæ of a brilliant brownish-black matter; which when examined in thin fragments, show the same reddish translucency as the resin just described, and are apparently similar to it in composition; although in some cases mingled with more coaly matter, and containing less ash. A specimen from one of these beds on the York river gave of volatile matters, 52·4; carbon, 26·3; residue, 21·3. The greater proportion of still more valuable hydrocarbons which may be obtained from this would render it still more valuable for distillation than the bed whose analysis has been given above.'

The Utica Shales.

Another probable source of material for oil-distillation is found in the great development of the Utica shales, which occur along the course of the St. Lawrence from the vicinity of the city of Quebec, as at Montmorency falls, as far west as the city of Montreal. Between these places, especially nearing the latter city, they occupy a large area along both sides of the river. Farther west in Ontario, they appear along the shore of Lake Ontario in the vicinity of Port Hope, and thence west to the shore of Lake Huron, being especially well displayed about Georgian bay, the Manitoulin islands, and in other places on the Ontario peninsula.

In 1859-1861, these shales were used for the distillation of oils with a fair amount of success, until the discovery of the oils of the Petrolia district put an end to the industry. Of the Utica shales of Collingwood, Dr. T. S. Hunt remarks, Geol. Can. 1863: 'These shales contain very variable amounts of combustible matter, and they give when distilled, besides inflammable gases, portions of oily matter, which in the shales of Collingwood, the richest yet examined, are equal to 4 or 5 per cent. Though the final results of the retorting of these shales are not now available the following details of operations at this place may be given (Geol. Can. 1863, p. 784):—

'In 1859, works for obtaining these oils were erected on the locality of this shale, near the town of Collingwood. Twenty-four longitudinal cast-iron retorts were set in two ranges, and heated by wood; of which 25 cords are said to have been required weekly. The shale, broken into small fragments, was heated for two or three hours; from eight to ten charges being distilled in 24 hours. In this way, it is said from thirty to thirty-six tons of shale were distilled daily, and made to yield 250 gallons crude oil, corresponding to about three per cent of the rock. By a further continuance of the heat, a small additional proportion of oil was obtained from the shale; but it was found more economical to withdraw the charge after 2½ hours. The bed of shale available for the purpose adjoins the works, and was furnished, ready broken, at twenty cents per ton. The cost of the crude oil from the shale was stated by the manufacturers to be fourteen cents per gallon. When rectified and deodorized, it gave from 40 to 50 per cent of burning oil, and from 20 to 25 per cent of pitch and waste, the remainder being a heavy oil fitted for lubricating purposes. After two or three unsuccessful trials, and the repeated destruction of the works by fire, they were at last, in 1860, got into successful operation, and a ready market was found for the oils. Data are, however, wanting to show whether the enterprise was remunerative; and it was after some time abandoned, partly, it is probable, on account of the competition of the petroleum of Enniskillen, which was about that time brought into the market in large quantities, and at a very low price. Should it, however, at any time, be found advantageous to renew the experiment of distilling the bituminous shales of this formation, those of Collingwood offer very favourable conditions, from their accessibility, and also for the ready means of transport afforded both by the lake and the railway.'

The position of these rocks was on lot 23 of range III, the thickness of the shale bed used being about 7 feet. The rock is highly calcareous, and from analyses of two samples from this place one gave to dilute acids 53 per cent, and another 58 per cent of carbonate of lime, with a little magnesia and oxide of iron. The insoluble snuff-brown argillaceous residue from the former, when ignited in a close vessel, gave off 12·6 per cent of volatile combustible matter, leaving a coal-black carbonaceous residue, which when calcined in the open air, lost 8·4 per cent additional, and became ash-grey. The insoluble residue from the second specimen was digested for some time with heated benzole, which took up from it about one

per cent of a solid bituminous matter. It then no longer gave out the odour of bitumen when heated, but a smell like that of burning lignite. The matter which had thus been treated with benzole still gave by ignition 11·8 per cent of volatile and inflammable matters. It was not attacked by a boiling solution of caustic soda. Portions of this shale, when distilled in close vessels, gave from 4 to 5 per cent of oily and tarry matters, besides combustible gases and water.

Other analyses of the Utica shales may be given, taken from a report on the Geology of Wisconsin, the analyses being made by Messrs. Chandler and Kimball, for Prof. J. D. Whitney.

—	I	II	III	IV	V
Clay and sand	38·45	34·60	37·26	48·27	73·57
Carbon	6·83	6·63	0·61	6·99	15·03
Hydrogen	0·74	0·77	0·83	1·13	1·65
Oxygen	3·20	2·96	1·71	3·39	5·39
Carbonate of lime	45·02	49·31	52·60	20·30	1·29
" magnesia	2·09	2·53	3·42	11·48	0·76
Alum. and oxide iron	2·16	2·09	3·29	7·99	2·79
	98·49	98·89	99·72	99·55	100·48

No. I is a brownish black, very fine grained rock from Cape Smith, Lake Huron.

No. II from an island to the north of Maple cape, Lake Huron and is blackish-brown, fine grained, and of earthy texture, with a laminated structure, and contains no fossils.

No. III from St. Anne, Montmorency, is a dark-brown shale, and contains graptolites.

No. IV is from Gloucester, near Ottawa, and is a black shale filled with fragments of trilobites and crinoids. In these analyses the carbonates of lime and magnesia, with the alumina and oxide of iron, were removed by solution in acids, and the elements of the organic matter were determined in the insoluble portion.

No. V is that of a pyroschist from this formation in the lead region of Wisconsin.

The black shales of Bosanquet on the southeast shore of Lake Huron, as seen at Kettle point, belong to the upper part of the Devonian formations. In a low cliff, it is remarked, on the west side of Cape Ipperwash, or Kettle point, is a section of between 12 and

14 feet of very fissile black bituminous shale, weathering to a lead-grey, and often stained brown with oxide of iron. (Geol. Can., 1863, p. 387.) Of these Dr. Hunt remarks that: 'A specimen of the schist, by ignition in a covered crucible, lost 12·4 per cent of volatile and inflammable matter, and left a black residue, which was not calcareous. Another portion, in fine powder, was digested for several hours with heated benzole, which dissolved 8 per cent of bituminous matter. The residue, carefully dried at 200° F., then gave off by ignition in a close vessel, 11·3 per cent of volatile matter, and by calcination lost 11·6 per cent more; equal to a total of 23·7 per cent of combustible and volatile substances. The calcined residue was grey in colour. By distillation in an iron retort there were obtained from the shale, in two experiments, 3·7 and 4·2 per cent of volatile liquid hydrocarbons, besides a large amount of inflammable gas, and a portion of ammoniacal water.'

He also states that 'these shales contain so much organic matter as to take fire and burn with flame, after which the colour is changed to brick-red. This is observed in the shingle of the beach, which has evidently been subjected to fire, and is reported by the Indians to have continued burning for a long time.' (Ibid. p. 388.)

At Manitoulin these Utica shales appear to be more than usually bituminous, and on the island north of Maple point a spring of petroleum rises from them. At Cape Smith the usual black bituminous shales of the formation are interstratified with a few bands of less bituminous character, grey in colour, and with an occasional thin layer of brownish limestone.

At Lake St. John the black bituminous shales of the Utica are also exposed over a considerable area, but no tests of their oil or ammonia contents have yet been made.

In fact, in all these analyses the ammonia appears to have been quite neglected, the tests having regard only to the percentage of oils. As at the present day the value of these shales as a source of sulphate of ammonia is very considerable, it will be very desirable that certain beds be examined for this substance, as well as for their contents in crude oil.

In the report of the Geological Survey for 1907, Mr. McInnes records the occurrence of soft, grey highly bituminous shales on the slopes of the Pasquia hills in northern Manitoba and along the valley of the Carrot river. They contain sufficient bituminous matter to

burn freely, and give out a strong odour of petroleum when heated in the fire. No attempts at analyses of these shales have been made.

In the North West Territories and in British Columbia no shales which have been recognized as oil-shales have yet been definitely discovered. The celebrated tar sands of the Athabaska river, in northern Alberta, may at some time furnish material for distillation, since all attempts to find oil by boring have hitherto been unsuccessful. These tar sands have been well described by Dr. Bell, and other officers of the Geological Survey who have visited the area. Dr. Bell, after describing the immense amount of tarry matter found along the river, states that 'the pitchy sand may itself be useful for a variety of purposes. When chopped out of the bank in lumps like coal it was found to burn freely, with a strong smoky flame, if supported in such a way as to admit of the free access of air. As the bitumen became exhausted the fine sand fell to the bottom.

'A very superior lubricating oil may be manufactured from it. Dr. Hoffmann, of the Geological Survey, Mr. Isaac Waterman, the well known petroleum refiner of London, Ont., and Lieut. Cochrane, instructor in practical chemistry at the Military College, Kingston, have found it to contain from 12 to 15 per cent of bitumen. Although this proportion may appear small, yet the material occurs in such enormous quantities that a profitable means of extracting the oil and paraffin which it contains may be found. The high banks of the river and its branches offer an easy means of excavating it, and as it burns readily one part might be consumed to extract the oil from another, there being practically no limit to the quantity which may be obtained for the digging. Dr. Hunt suggests that the lighter and less valuable oils obtained in the process of distilling might be used to percolate through or lixiviate large masses of the crude material, and that in this way a large proportion of the better part of the oil which it contains might be cheaply obtained on a commercial scale. Dr. Hoffmann found that in the sample he tried, 69·26 per cent of the bitumen was removed by boiling or macerating in hot water, the extracted bitumen containing 50·1 per cent of sand. This might be found a good method of reducing the bulk of the material to be distilled for oil or for the purpose of making gas. The natural tar which has been already referred to may be found to exist in sufficient quantities to be available for the manufacture of oil. Mr. Waterman informed me that the proportion of paraffin in the bitumen of the sample submitted to him appeared to be large, and it is possible that

this substance might be profitably extracted for export from the deposits which have been described.'

As to the mode of occurrence of this remarkable deposit Dr. Hoffmann remarks, in the Geol. Surv. Report for 1880-1-2, on the evidence of Dr. R. Bell, 'that the deposit is of Cretaceous age, but rests directly upon the limestone of the Devonian system. The bedding of the latter undulates gently, while the asphaltic sand lies in thick horizontal layers upon its surface, and in some cases fills fissures in the upper part of the limestone. The asphaltic matter has no doubt resulted from petroleum rising out of the underlying Devonian rocks, in which evidence of its existence can be detected. In descending the Athabaska river it was first observed a few miles above the junction of the Clearwater branch, below which it becomes more conspicuous, forming the whole banks of the stream, with the exception of a few feet of limestone at the base, for a distance of many miles. These banks are sometimes about 150 feet high, and frequently maintain an elevation of over 100 feet for considerable distances. Except where they have been long exposed to the weather they generally look as black as coal. A thick tar is often seen dripping out of this deposit, and in numerous places, on the ground and at the foot of either bank, or on terraces lower than the summits, this tar collects in pools, or flows in sluggish streams to lower levels among the peaty materials in the woods. The surface of these accumulations of tar is usually covered with a hardened pitchy crust. The boatmen on the river break through this crust in order to collect the underlying tar, which they boil down and use for pitching their craft. Some parts of the bank are rendered plastic *en masse* from being over saturated with the asphalt, and in warm weather they slide gradually down into the bed of the river, incorporating the boulders and pebbles in their course.'

An analysis was made of the material from this place by Dr. Hoffmann. He says: 'the specimen was compact and homogeneous in appearance, and of a dull, dark brownish-black colour. Sp. gr. at 60° F., 2·040. At a temperature of 50° F. it is quite firm, barely, if at all, yielding to pressure, and does not soil the hand; at 70° F. it gives somewhat to the touch, and is slightly sticky; at 100° F. it becomes quite soft and soils the fingers. It is scarcely acted on by alcohol when cold, and but very slightly at a boiling temperature; but ether, oil of turpentine, kerosene, benzine (petroleum spirit), benzol, (coal tar naphtha) and bi-sulphide of carbon, more especially the last

two, readily dissolve the bituminous matter, with formations of dark-brown coloured solutions, and leave a pure or almost pure siliceous residue in the form of sand, of which apparently the bitumen has constituted the sole binding medium.

'The composition of this specimen of the rock was found to be as follows:—

	Per cent
Bitumen..	12·42
Water, mechanically included..	5·85
Siliceous sand..	81·73
	100·00'

Of the maltha or mineral tar which occurs so abundantly at this place, as also at other places along this river, Dr. Hoffmann remarks that 'as regards the utilization of these substances—the most appropriate application of the former, and that for which it would appear to be admirably adapted, would be for asphalting purposes. It has one of the most important qualifications of a good bituminous concrete, viz., intimate combination of the mineral and organic constituents, and this in a degree which no artifical preparation of the kind could be expected to possess. It will in all probability be found that a very slight treatment will render it suitable for employment in construction of roads, foot-paths, court-yards, etc., for asphalting the flooring of granaries, basements of warehouses, and the like, and further as a roofing material. Should it be deemed more expedient to separate the bitumen, this may be effected by simply boiling or macerating the material with hot water, when the bituminous matter, entering into fusion, will rise as a scum to the surface, and may be removed by skimmers while the sand falls to the bottom of the vessel.

The sand separated by this process, when carefully conducted, is free, or almost free, from bitumen, and might after being heated to redness in a reverberatory furnace—to destroy any little adhering bitumen—be advantageously employed for the manufacture of one of the better qualities of glass. He adds: 'Should it (the maltha) occur in sufficient quantities, it might possibly, amongst other uses, be advantageously employed as a crude material for the manufacture of illuminating and lubricating oils and paraffin.'

Origin of Oils.

The source of supply for the oils, both native and those contained in the shales, has long been a subject for controversy. The two theories as to their origin are the organic and the inorganic, the principal evidence hitherto brought forward appearing to support the former. This subject of the organic origin of mineral oils has been very thoroughly presented by Mr. J. E. Carne in his volume on the Kerosene Oil-shales of New South Wales, 1903, and has recently been discussed by Mr. D. R. Steuart in the Oil-shales of the Lothians, issued by the Geological Survey of Scotland, 1906, from which the following extracts may be made. He says, (p. 142): 'for convenience of description we may apply the name kerogen to the carbonaceous matter in shale that gives rise to crude oil by distillation. This term kerogen was suggested by Professor Crum Brown, late of Edinburgh University. It is regarded as the valuable material in oil-shale as regards the oil-contents of that substance, and this value depends very largely on the amount of carbonaceous matter. This carbonaceous matter in the form of mineral paraffin, or paraffin oil, does not exist in the shale as such. It cannot be obtained by boring as in the case of ordinary rock oil, and the containing rock will yield up its valuable contents only by a process of distillation. The term kerogen has been used, therefore, to indicate this carbonaceous matter in shale beds that give rise to crude oil by distillation.'

Though the view has long been held by various persons that crude oil can be obtained from these shales by boring, it must be acknowledged that this view is not supported by the results obtained hitherto at the extensive works carried on in Scotland, either through exploration by boring or by underground workings; or in the Provinces of Quebec, Nova Scotia, or New Brunswick. In the Scotch field it is held that paraffin and paraffin oil do not exist as such, but are created by destructive distillation in retorts, and so far as bituminous or oil-shales are concerned this remark will, without doubt, be found to hold good. It is also held as certain that the substance kerogen is of organic origin.

As for the origin of the shale beds, they are now generally regarded as having been deposited in the form of fine clays at the bottom of lagoons or swamps, with frequently much vegetable and sometimes much animal matter, the latter chiefly in the form of fishes, as can be readily observed in the many collections of fossils made

from the shales, both in Scotland and America. It is not, however, necessary to suppose that the oils or bituminous matters are the result of the decomposition of such organisms. The more plausible theory is that put forward by Mr. Steuart in his paper, viz., that the deposits in the swamp or lake bottoms have been subject to maceration and microbe action. Part would be decomposed, and only what could withstand the water, etc., would remain. This mode of deposition agrees very closely with that suggested by Sir W. E. Dawson, many years ago, who regarded the oil-shales of eastern Canada as originating in swampy lagoons, and that the resulting bituminous contents were the result of the decomposition of various organisms enclosed in the original clayey mud of the swamp bottom. In this case also the oily contents may have been subjected to a form of natural distillation.

Some shales are largely made up of entomostraca, and it is probable that the animal matter has, in some cases, been converted into kerogen, or it may owe its origin in part to remains of certain kinds of vegetable matter. Laboratory experiments made in Scotland with a mixture of Fuller's earth and spores of lycopodiaceous plants, or spore dust, subsequently distilled in the laboratory and then retorted, were found to yield a fair amount of crude oil, equal to 23·8 gallons per ton, sp. gr. 0·930 and sulphate of ammonia 3·3 lbs. per ton being obtained. The results from these experiments agreed very well with those obtained from the distillation of Torbanehill mineral, and from some of the higher shales.

Mr. Steuart further remarks that 'as peat gives paraffin products on distillation very like those from shale it is probable that shale contains ordinary vegetable or organic matter that has undergone decay, together with substances of a humic acid nature which have been rendered insoluble and preserved by chemical combination with the metallic oxides of the clay and water, the alumina, lime, etc. During the deposition of the sediments the climate may have varied, and the vegetation on the shores producing pollen, spores, and seeds may have changed together with the algae.

'Oil-shale may, therefore, be composed: (1) of vegetable matter which has been made into a pulp by maceration with water and preserved by combining with the salts in solution as already mentioned; (2) richer materials of many kinds, such as spores, which nature has provided with means for some protection against decay; and (3) a proportion of animal matter.' Reviewing the literature on the sub-

ject we may, therefore, conclude that the probable origin of these shales, and of their bitumen contents as just stated, may be accounted for on a fair basis of reason; and that the origin of petroleum in shales is the result of fermentations and decompositions on the surface, through microbe action. Such action may be increased by the agency of heat from volcanic masses or from some other source; and the petroleum is often associated with brine or sea-water which in some of the ancient lagoons became shut off from the sea.

Natural gas is found in some of the oil-shale districts in Scotland in considerable quantities, issuing with water from bore-holes in the oil-shales. With the underground development the outflow of the water gradually ceased, but in some cases can still be recognized. The source of this gas is said to be either from fire-damp given off from underlying coals and oil-shales, or a permanent gas induced by the action of molten igneous rocks intruded into the oil-shales themselves. In Scotland the action of such intrusive masses is readily recognized in many places, either by the debituminization of the shales or by the general alteration of the sediments in contact with the intrusive mass.

APPENDIX.

Oil-shale found on Melville Island, 1909.

Among the specimens collected by Captain Bernier during the recent voyage of the SS. *Arctic* were some very rich, black oil-shales, which were picked up on the beach of Melville island, inside the Arctic circle. These specimens are exceedingly rich in hydrocarbons, kindling very readily into flame when ignited by a match. They are apparently of the same class, and are probably of the same horizon as the oil-shales of New Brunswick, Newfoundland, and those recorded from Bear island, near Spitzbergen.

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